

**Air-and-N<sub>2</sub> broadening parameters of water vapor; 604 to 2271 cm<sup>-1</sup>**

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## ABSTRACT

High resolution measurements of air and N<sub>2</sub> broadened widths and pressure-induced frequency-shifts of water vapor were obtained covering the spectral region between 604 and 2271 cm<sup>-1</sup>. Over 1300 vibration-rotation transitions were measured including the (000)-(000), (010)-(010), (010)-(000), (020)-(010), and (100)-(010) vibrational bands of H<sub>2</sub><sup>16</sup>O. Also included were measurements of H<sub>2</sub><sup>18</sup>O and H<sub>2</sub><sup>17</sup>O from normal water vapor samples and H<sub>2</sub><sup>18</sup>O + N<sub>2</sub> observations with oxygen-18 enriched gas samples. Collision narrowing effects were observed in a few lines involving high J and low K<sub>a</sub> transitions with the lowest measured linewidth coefficient equal to 0.0057(4) cm<sup>-1</sup>/atm. (air-broadening) for the completely overlapping transitions, 17 0 17 - 18 1 18 and 17 1 17 - 18 0 18, at 1235.204 cm<sup>-1</sup>. The majority of the linewidth values were derived from the measurements using a Voigt line profile. A few lines with air- or N<sub>2</sub> -broadened half-width values of about 0.012 cm<sup>-1</sup> or less were found to exhibit collision narrowing effects and were also analyzed with a profile proposed by Galatry. The results are compared to values given in previous studies.

## 1. INTRODUCTION

In a recent study(1), we presented an extensive listing of the self-broadening parameters of water vapor covering the 600 to 2300  $\text{cm}^{-1}$  region. In the present work, the self-broadening values(1) were used in the analyses in order to obtain accurate values of linewidths and pressure-induced frequency-shifts for air and  $\text{N}_2$  broadening measurements.

Other experimental investigations involved in foreign-broadening of water vapor in this spectral region include the following studies:  $\text{H}_2\text{O+air}$  widths for the region between 800 and 1150  $\text{cm}^{-1}$  by Rinsland et al.(2),  $\text{H}_2\text{O+Argon}$ ,  $\text{H}_2\text{O+N}_2$ ,  $\text{H}_2\text{O+O}_2$ , and  $\text{H}_2\text{O+air}$  widths and shifts for 20 lines in the  $\nu_2$  and  $2\nu_2-\nu_2$  bands by Giesen et al.(3),  $\text{H}_2\text{O+air}$  widths and shifts for 271 lines between 1211 and 2091  $\text{cm}^{-1}$  by Yamada et al.(4),  $\text{H}_2\text{O+air}$  widths for 91 lines in the  $\nu_2$  band between 1801 and 2091  $\text{cm}^{-1}$  by Chang and Shaw(5), and tunable diode laser measurements by Eng and other collaborators(6-9), and by Mucha(10). In the first study, Eng et al.(6) measured the completely overlapping rotational transitions, 16 0 16 - 15 1 15 and 16 1 16 - 15 0 15, at 1879.019  $\text{cm}^{-1}$  and were the first to report measurements of collision narrowing effects in water vapor with argon, xenon, and nitrogen as buffer gases. They(6) observed line narrowing (and increased absorption) for foreign gas pressures below 250 Torr and normal pressure-broadening effects above a few hundred Torr. Grossmann and Browell(11) discussed these effects in detail and showed deviations resulting from line narrowing between measured profiles and the Voigt profile using tunable-dye laser

measurements of  $\text{H}_2\text{O}$  self-broadening in the  $13,558$ - $13,966 \text{ cm}^{-1}$  region. They(11) applied a hard collision profile in their calculations and found that when the data were analyzed with a Voigt profile, the corrections ranged from +17% at  $b_d/b_c=1.5$  down to +6% at  $b_d/b_c=0.6$  where  $b_d$  and  $b_c$  are the Doppler and collision widths, respectively. Valentin et al.(12) reported  $\text{N}_2$ -pressure-induced shifts of 109 lines between  $1842$  and  $2212 \text{ cm}^{-1}$ .

The measurements in the present study include a few lines that exhibit collision narrowing effects and they were analyzed with a Voigt function and a hard collision-type profile which compensates for the Voigt profile. The pressure-broadened widths and pressure-induced line-shifts of over 1300 lines were measured covering transitions in the (000)-(000), (010)-(010), (010)-(000), (020)-(010), (100)-(010) and (001)-(010) bands of  $\text{H}_2^{16}\text{O}$  and the (000)-(000) and (010)-(000) bands of  $\text{H}_2^{18}\text{O}$  and  $\text{H}_2^{17}\text{O}$ .

## 2. EXPERIMENT

The experimental conditions of the laboratory spectra used in this work are summarized in Table 1 which gives the path, sample pressures, sample temperatures, broadening gas, and molecules used for frequency calibration. The data were recorded with a Fourier transform spectrometer (FTS) located in the McMath solar telescope facility at the Kitt Peak National Observatory. The spectral resolutions of the runs were near or at  $0.0054 \text{ cm}^{-1}$ . The sample pressures were measured with a Baratron gauge with a ten ( $\text{H}_2\text{O}$  sample) and 1000 (foreign gas) Torr pressure heads. The 1000 Torr head was calibrated against room air pressure (~600 Torr) which was

measured to high accuracy with a mercury manometer just before the calibration procedure. The filling of an absorption cell was performed as follows: the low pressure H<sub>2</sub>O sample was entered into the cell and after a few minutes the pressure was measured and then the buffer gas was then let into the cell and the total pressure was measured. After 10 minutes or longer, the initial interferogram was started with total sample pressures continuously recorded during the run. The same procedure was followed for recording sample temperatures which were inferred from readings of one or more thermistor probes in thermal contact with the absorption cell walls.

The infrared radiation originating from a globar source passed initially through the absorption cell and then entered the vacuum tank which enclosed the FTS and finally was collected onto a helium-cooled arsenic-doped Silicon single element detector. Each FTS run consisted of 12 or more co-added interferograms and the composite interferograms were transferred into spectral data at the Kitt Peak facility.

The spectral runs obtained with path lengths of 25 m or longer listed in Table 1. were made with the use of a 6-m base length multiple pass transversal absorption cell. The optical path from the 6-m cell to the entrance of the vacuum tank contained a 2.39m long cell, which for several runs, contained N<sub>2</sub>O at low pressure (0.2 Torr) for purposes of frequency calibration. The rest of the optical path (~5.1 m) before the vacuum tank entrance contained several compartments which were purged with dry N<sub>2</sub>. This setup

greatly reduced interference from  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ , and  $\text{CH}_4$  spectral absorptions due to room air in the "open" optical path. The runs obtained with room air in the 6-m cell showed pressure-broadened features due to  $\text{CO}_2$  and  $\text{CH}_4$ , and to a lesser extent,  $\text{N}_2\text{O}$ . The low pressure  $\text{N}_2\text{O}$  lines observed in these runs were much stronger than their pressure-broadened counter-parts. As noted or inferred from the footnotes at the bottom of Table 1, very little or no detectable  $\text{N}_2\text{O}$  and  $\text{CO}_2$  and no  $\text{CH}_4$  pressure-broadened features were observed in the spectral data relating to the buffer gases, dry air and  $\text{N}_2$ , respectively.

The vacuum tank contained very low pressure ( $\sim 200 \mu\text{m}$ ) residue room air which contained enough  $\text{H}_2\text{O}$  and  $\text{CO}_2$  so that the strongest absorptions of these molecules were observed in empty cell runs. The empty cell runs were made before and/or after a set of runs were obtained and were used as an added aid for frequency calibration with  $\text{H}_2^{16}\text{O}$  lines ( $S > 0.01 \text{ cm}^{-2}/\text{atm}$ ) of the (010)-(000) band and the strongest transitions of  $\text{CO}_2$  of the  $v_2$  band below 700 and the  $v_3$  band above  $2300 \text{ cm}^{-1}$ . The  $\text{H}_2\text{O}$  pressure-broadened lines observed in the 6-m cell runs swamped the low pressure contributions to the extent that the narrow features could not be measured and this was also the case for the low pressure  $\text{CO}_2$  lines involved in the 6-m cell runs with room air as the broadening gas. The empty cell runs are not listed in Table 1.

Two of the runs listed in Table 1 (denoted with an asterisk) show path lengths at 2.39 m with  $\text{H}_2^{18}\text{O}$  as the absorbing gas. The water vapor samples used for these runs were oxygen enriched at 98%

$O^{18}$  and the buffer gas was  $N_2$ . The experimental set-up for these runs had the source situated near one window of the cell with a pre-filter placed between the source and window in order to minimize heat exchange between source and cell contents. The other window was placed near the entrance to the vacuum tank. The strongest absorptions due to  $H_2^{16}O$  in the vacuum tank were easily observed in the spectra and, for the most part, displaced from the pressure-broadened  $H_2^{18}O$  lines.

The entries in Table 1 with path lengths of 0.25 m, 1.5m, and 1.75m represent data obtained with two stainless steel absorption cells (0.25m and 1.5m) that were placed in series and located between the source and vacuum tank entrance. All portions of the external path and the source enclosures were evacuated by using some newly-installed apparatus. The majority of the runs with absorption path lengths equal to 0.25m also included 0.04 Torr of CO in the 1.5 m cell and lines of the fundamental band of CO as well as the low-pressure  $H_2^{16}O$  lines originating from the vacuum tank were used for frequency calibration whereas for the other short path length runs, only  $H_2^{16}O$  was used as the calibration species.

### 3. SPECTRAL ANALYSIS

The parameters were retrieved from the spectra using a non-linear least-squares (NLLS) curve-fitting technique which modifies, if necessary, the input values of positions, strengths, and widths in the computed spectrum to minimize the differences between the observed and computed spectra. The initial parameters (positions

and strengths) of  $H_2O$  and HDO were generated from computed values of line positions and strengths for the following bands and isotopic species: the (000)-(000), (010)-(010) and (010)-(000) bands of  $H_2^{16}O$  from Toth(13), the (020)-(010), (100)-(010) and (001)-(010) bands of  $H_2^{16}O$  from Toth(14), the (000)-(000) and (010)-(000) bands of  $H_2^{17}O$  and  $H_2^{18}O$  from Toth(15), and the (010)-(000) bands of  $HD^{16}O$  and  $HD^{18}O$  from Toth(16,17). The (000)-(000) line strengths of  $H_2^{17}O$  and  $H_2^{18}O$  were derived from the parameters given for  $H_2^{16}O$ (13) and normalized to the concentration of the respective isotopic species. Line positions and strengths of the (020)-(010) band of  $HD^{16}O$  were also included and the parameters used to generate the computed values were from ref.(17).

Other inputs to the NLLS routine included self and foreign gas partial pressures and self- and foreign-broadened width coefficients. The non-adjusted self-broadened  $H_2O$  linewidth coefficients were taken from the listing of "smoothed" values given by Toth et al.(1) whereas the HDO self-broadened values were given a constant value of  $0.4 \text{ cm}^{-1}/\text{atm}$ . The HDO features were of minor concern in the fitting procedure and the HDO as well as the  $H_2O$  fitted results were adjusted in the NLLS program by the expression:

$$b = b^o_f p_f + b^o_s p_s , \quad (1)$$

where  $b$  is the measured width,  $b^o_f$  and  $b^o_s$  are the foreign and self-broadened width coefficients, respectively, and  $p_f$  and  $p_s$  are the foreign and self-broadened partial pressures. The HDO results are

not given here but are included in an presentation of results derived from an analysis of HDO samples (~50% HDO) broadened by air and N<sub>2</sub>(18).

The experimental method of filling the absorption cell with H<sub>2</sub>O and the buffer gas was described in the last section. In many cases, the H<sub>2</sub>O partial pressure of a run derived from spectral analysis did not agree with the recorded H<sub>2</sub>O pressure due to residue water vapor adsorbed into the cell walls before the foreign gas was entered which then removed some of the H<sub>2</sub>O from the walls after the final filling. By this token, the partial pressures of H<sub>2</sub>O given in Table 1 were derived from spectral analysis and not the recorded values from the pressure gauge and the buffer gas pressures given were the differences between the total pressure readings and the derived H<sub>2</sub>O partial pressures. The transitions used in this procedure were of the (000)-(000) and (010)-(000) bands of H<sub>2</sub><sup>16</sup>O with the strength values from Toth(13). As noted in Table 1, several runs were made at sample temperatures different from 296K and for these, the line strengths were computed at the same temperature, T, as the sample using the expression:

$$S(T) = S(296) (296/T)^{5/2} \exp\{-1.44E''(1/T - 1/296)\}, \quad (2)$$

where S is the line strength and E'' is the lower state rotational energy of the transition.

The N<sub>2</sub>O parameters required for the input list for some of the runs were computed from line position and strength coefficients

given by Toth(19,20). Parameters for CO, CH<sub>4</sub>, and CO<sub>2</sub> were taken from the HITRAN(21) database. The HITRAN(21) listing contains air-broadened linewidth coefficients for H<sub>2</sub>O and HDO however no lineshift information is given. For this work, the parameters noted were used as inputs to the NLLS for a few of the air-broadened runs and the resulting outputs were averaged. The linewidth and lineshift data obtained from this preliminary analysis was then used as inputs from which the final air-broadened results were derived. The input linelist for the N<sub>2</sub>-broadened spectra included linewidth coefficients set equal to 1.1 times the preliminary air-broadened values for each transition whereas the shifted positions were the same as those used in the preliminary list.

As noted earlier, a small amount residual water vapor was found in the vacuum tank which enclosed the FTS and these narrow, extra features were observed in the short path length spectra superimposed upon the pressure-broadened counterpart. They were effectively modeled for these runs in the NLLS program by inputting two components for each H<sub>2</sub>O transition. The narrow H<sub>2</sub>O features were present in all of the spectra but were not readily observable in the long path spectra because they were swamped by the pressure-broadened counterparts or they were too weak in absorption to appear. The minimum line strength of a H<sub>2</sub>O narrow absorption that was observed in the empty cell runs was about 10<sup>-2</sup> cm<sup>-2</sup>/atm which happened to be about the same minimum strength of air-broadened H<sub>2</sub>O lines resulting from room air in the open space, optical path

between the exit of the 6-m cell and the entrance to the vacuum tank. In any case, the long-path runs were modeled in the NLLS program by inputting three components for each H<sub>2</sub>O transition although the narrow and the open space room air components were of little or no consequence in the analysis and in many situations, were removed after one or two iterations of the NLLS program.

The majority of the pressure broadened lines observed in all the spectra exhibited Lorentzian or Voigt profiles which were accurately simulated in the NLLS program. In a few cases, the line shape was altered in which the line narrows and this effect is usually referred to as collision narrowing although the form of the pressure broadening contribution to the combined effect does not change. The Doppler shape and width apparently change from the standard representations and the superposition of line shapes produce a function which is complicated and, like the Voigt profile, can only be solved accurately in digitized form. The sub-Doppler behavior of these types of rotational transitions can occur over a wide pressure range.

The line shape algorithm that was included in the NLLS program and used in the analysis of narrowed lines was the Galatry(22) profile based on the description given by Varaghese and Hanson(23). The function involved the hard collisions model which includes the same parameters as those applied in the Voigt function with the addition of a collision narrowing coefficient,  $\eta$ , given in units of cm<sup>-1</sup>/atm.  $\eta$  was allowed to float in the fitting procedure and typical values for  $\eta$  ranged from 0.04 to 0.09 cm<sup>-1</sup>/atm. with the

smallest values corresponding to the narrowest lines. Grossmann and Browell(11) obtained similar results for self-broadened water in the 0.735  $\mu\text{m}$  spectral region.

Eng et al.(6,7) studied this problem in detail for the  $\text{H}_2^{16}\text{O}$  16 0 16 - 15 1 15 and 16 1 16 - 15 0 15 transitions, both located at 1879.0194  $\text{cm}^{-1}$ . They observed collision narrowing for this feature with the buffer gases: xenon and argon(6) and  $\text{N}_2$  (7) but found no effects due to self-broadening(7). They derived the pressure broadening coefficient for each foreign broadening agent from the slope of the curve produced from a plot of measured linewidths vs. pressures. This method works if the Doppler width,  $b_D$ , decreases with pressure to a value of zero or near zero in the vicinity of the higher broadening pressures used in the experiment. For the case of  $\text{H}_2^{16}\text{O}+\text{N}_2$ , they(7) derived  $b^0$  from measurements of linewidths with  $\text{N}_2$  pressures ranging from 20 Torr to 1 atm.

The type of  $\text{H}_2^{16}\text{O}$  lines affected by collision narrowing are the high  $J$ , low  $K_a$ , P- and R-branch transitions with  $b^0(\text{air})$  values of about 0.014  $\text{cm}^{-1}/\text{atm}$ . or less. A few of these types of transitions are displayed in figures 1-4. The first two figures shows the doublet located at 1879.019  $\text{cm}^{-1}$ . Each spectral scan shows the observed and synthetic spectra along with the residual plots (above) which gives the percent differences between observed and computed spectra. Inspection of the fig.1 shows that the Voigt results does not completely simulate the observed absorption by noting in the residual plot, the two spikes located on both sides

and near the center of the feature. Fig 2 shows excellent agreement between the synthetic (Galatry) and observed spectra. Figs. 3 and 4 show similar plots with the same results for the  $15\ 1\ 14 \leftarrow 14\ 2\ 13$  ( $1915.196\text{ cm}^{-1}$ ) and  $15\ 2\ 14 \leftarrow 14\ 1\ 13$  ( $1915.270\text{ cm}^{-1}$ ) transitions. The values of  $b^\circ$  derived using the Galatry function were found to be larger than their respective counter values obtained from the Voigt analysis. For example, the Galatry result for  $b^\circ(\text{air})$  for the doublet lines at  $1879.019\text{ cm}^{-1}$  was  $0.072(2)\text{ cm}^{-1}/\text{atm}$ . whereas the value obtained from the analysis using the Voigt function was  $0.064(2)\text{ cm}^{-1}/\text{atm}$ . This trend followed a pattern in which the smallest width values showed the largest differences between the Galatry and Voigt results with the added feature that the smaller the width, the higher the  $|m|$  value. An accurate relationship was derived from these results which can be given as:

$$b^\circ(V) = b^\circ(G) [1 + a_1|m| + a_2|m|^2]$$

with  $|m| \geq 11$ , (3)

where  $b^\circ(V)$  and  $b^\circ(G)$  are the Voigt and Galatry results for either air- or  $N_2$ -broadening.  $|m|$  is  $J''$  for P-branch lines and  $|m|=J'$  for R-branch transitions and prime and double prime denote upper and lower states, respectively. The values of  $a_1$  and  $a_2$  were found to be 0.0177 and -0.00158, respectively. It should be noted that eq. (3) only applies to narrowed lines and that the pressure broadened widths of the other transitions were accurately derived using the Voigt function.

The narrowed lines were also analyzed with the Voigt function in which the molecular weight (M.W.) input to the NLLS program was given much larger values than that of  $H_2^{16}O$  (M.W.=18) which, of course, reduces the value of  $b_D$ . The results show good agreement with the observed spectra but not quite as good as the results obtained with the Galatry profile. As an example, the Voigt analysis of the feature at  $1879.019\text{ cm}^{-1}$  for the spectral run with 498 Torr air and a path of 73 m and M.W.=100 and shown in figure 5, gave a value of  $0.072\text{ cm}^{-1}/\text{atm.}$  for  $b^\circ(\text{air})$  which was the value derived from the analysis using the Galatry algorithm. This result and others obtained here (not reported) plus the findings of Eng et al. (7) indicate that the narrowed lines in this spectral region can be modeled accurately using a Lorentzian profile for air- or  $N_2$ -broadening pressures of about 500 Torr and greater.

#### 4. RESULTS

In a recent paper by Toth(13), measured and computed line positions and strengths were determined but not listed for the (000)-(000) and (010)-(000) bands of  $H_2^{16}O$ . It was stated in that paper that they would be presented in the present study. Table 2 presents the majority of the lines measured in the present study for the (010)-(000) band of  $H_2^{16}O$ . The complete listing can be obtained from the author by e-mail or floppy disk. The table includes results for width (HWHM) and pressure induced frequency shift coefficients,  $b^\circ$  and  $d^\circ$ , respectively. The table gives the computed "zero" pressure line position and uncertainty,  $u_n$ , in the position, the rotational quantum assignments, observed strength,

estimated uncertainty in the strength in percent, %s, the observed minus computed strength in percent, (o-c)%, and the linewidth and shift information. The computed positions were calculated from the rotational energy levels given in ref.(13) and the values of un were determined from the uncertainties for the energy level values given in the paper. The linewidth data list air-broadened smoothed,  $b^\circ(\text{sm})$  and observed,  $b^\circ(\text{obs.})$  and  $N_2$ -broadened observed coefficients, respectively, and the same type of results are given for the pressure-induced frequency shifts,  $d^\circ$ .

The smoothed values of linewidth and shift coefficients,  $b^\circ(\text{sm})$ , and  $d^\circ(\text{sm})$ , were derived from an analyses of the experimental values for "families" of rotational transitions. Within a "family" of transitions, the rotational quantum numbers obey the following rules:  $\Delta J$ ,  $\Delta K_a$ ,  $K_a''$  and  $\gamma''$  are each the same and  $\gamma$  is 0 or 1 where  $\gamma$  is defined as:

$$\gamma = K_a + K_c - J \quad (4)$$

and double prime denotes the lower state. In most cases, the half-widths of two related families follow the same pattern. Also in the related families the following may occur as follows:

$$b^\circ(1\leftarrow 2) = b^\circ(2\leftarrow 1)$$

where  $b^\circ(1\leftarrow 2)$  of  $J(1) K_a(1) K_c(1) \leftarrow J(2) K_a(2) K_c(2)$

and  $b^\circ(2\leftarrow 1)$  of  $J(2) K_a(2) K_c(2) \leftarrow J(1) K_a(1) K_c(1)$ . (5)

which shows rotational quanta reversed in value and termed "rotational reversal" in this study.

A smoothing function was used to determine smoothed values of  $b^o$  within a family of transitions. The function is given as:

$$b^o = \exp\{\sum_i a(i) |m|^i\}$$

where  $i=0, 1, 2, \dots$ , (6)

and  $|m|$  was defined earlier. The experimental  $b^o$ 's of a family of transitions were least-squares-fitted using eq. (6) and in most cases, an accurate fit was obtained with four or five coefficients,  $a(i)$ . This method has been applied with success for  $N_2O$  half-widths broadened by air and  $N_2$  (24). Only smoothed values of air-broadened  $b^o$ 's of  $H_2^{16}O$  for the (000)-(000) and (010)-(000) bands were derived in this study. 65 families of transitions were fitted in this manner of which about 1/2 of these were analyzed with rotational reversal.

The pressure-induced frequency shifts were derived from the NLLS results and an expression similar to eq. (1),

$$d = d_f^o p_f + d_s^o p_s, \quad (7)$$

where  $d$  is the difference between the measured and computed (zero pressure) line center frequency and  $d_f^o$  and  $d_s^o$  are the foreign and self shift coefficients, respectively. The self-broadened  $H_2O$  coefficients given in ref. (1) were used along with the

experimental d's and eq. (7) to obtain the  $d_f^o$ 's that are listed in Table 2. On the average, the contribution of  $d_s^o p_s$  for determining  $d_f^o$  was small which was a satisfactory finding because it is not known from theory that eq. (7) is valid in terms of the sum of the two parts resulting in the value for d. Theory may show that d comes from a complicated combination of the two. The pressure shift coefficients,  $d^o$ , given in Table 2 do not have nearly the smooth behavior as that of the width coefficients in terms of the quantum numbers. The smoothed values assigned to  $d^o(\text{sm})$  in the table for air-broadening are, in most cases, equal to the observed values. The remainder of the smoothed values were derived from hand drawn plots of families of transitions. Also pairs involving the same quantum numbers (rotational reversal) often have shifts that are opposite in sign. This is displayed in Fig. 6 for the pairs:  $\Delta K_a = 1$ ,  $K_a'' = 0$  (R-branch), and  $\Delta K_a = -1$ ,  $K_a' = 0$  (P-branch), which shows one family to be nearly a mirror image of the other family and this behavior in  $d^o$  was also found in H<sub>2</sub>O self-broadening(1) for these transitions.

Values denoted with an asterisk, \*, in Table 2 represent doubled transitions in which the strength given is the sum of the strengths of the two lines and the rotational quantum numbers pertain to the stronger of the two comparable transitions. In many cases, the two absorptions are nearly or completely overlapped. In some, the two lines are separated by up to 0.004 cm<sup>-1</sup> however the estimated uncertainties assigned to them (given within parentheses after the observed values of  $b^o$  and  $d^o$ ) should be realistic due to

the accurate simulation of the observed spectra using the NLLS program.

Table 3 is an abbreviated list of the results for the (000)-(000) band of  $H_2^{16}O$  and is similar in format to that of Table 2. Although smoothed values were not derived for  $N_2$  broadening, the ratios of observed coefficients for  $N_2$  to air broadening were obtained. For  $b^\circ$ , the ratio was found to be  $1.12 \pm .03$  from the analysis of 468 lines with experimental uncertainties in the  $b^\circ$ 's of 4% or less. The frequency shift ratio was  $1.14 \pm .12$  for 284 lines analyzed with uncertainties in the  $d^\circ$ 's of 10% or less.

Table 4 gives results for  $N_2$ -broadening of  $H_2^{18}O$  and compares with those of the same transitions in  $H_2^{16}O$  for the (010)-(000) bands (band=2 in the table). The  $H_2^{18}O$  values were mainly derived from the two spectra with enriched  $O^{18}$   $H_2O$  samples listed in Table 1. The  $H_2^{18}O$  computed positions given in Table 4 were calculated from the energy levels given in ref. (15). Note that the values of  $d^\circ$  are given in  $\text{cm}^{-1}/\text{atm.} \times 10^5$  whereas those given for  $d^\circ$  in Tables 2 and 3 are given in the same units  $\times 10^4$ . The reason for the "shortened" values in the earlier tables was for simpler viewing however computer output (available upon request) from these tables will be given with the complete values of  $d^\circ$ . Inspection of Table 4 reveals that, on the average, there is good agreement between the isotopic species for the values of  $b^\circ$  and  $d^\circ$  which is an assumption made in the HITRAN compilation(19) for  $b^\circ(\text{air})$ . Table 5 lists the measured air-broadened parameters for the  $H_2^{16}O$  "hot" bands, (020)-(010) (band=3), and (100)-(010) (band=4). Also given in the table

are the smoothed air-broadened values of  $b^\circ$  and  $d^\circ$  for the (010)-(000) band of  $H_2^{16}O$ . To demonstrate the behavior of the parameters between the two "hot" bands as well as the smoothed values, the measurements are given in terms of transitions rather than increasing frequency. The measurements in the (100)-(010) band are sparse but even with few comparisons, one can tell from inspection of Table 5 that the largest differences in  $d^\circ$  between the "hot" band results and the ground state values involve the (100)-(010) band.

##### 5. COMPARISON WITH OTHER STUDIES

Rinsland et al.(2) measured 63 lines in the  $800-1150\text{ cm}^{-1}$  region and obtained line strengths and air-broadened linewidths from atmospheric data at the McMath facility. The path lengths ranged from 0.5 km to 1.5 km over horizontal paths. Table 6 lists their values along with those of this study for these transitions. Line positions denoted with an asterisk represent transitions in the (010)-(000) band while the others are for the (000)-(000) band. Inspection of the table shows very good agreement between the two sets of data. They(2) determined the  $H_2O$  partial pressures for each run from temperature and humidity readings and converted their results to values at 296K. They also corrected their linewidth values for the effects of self-broadening by assuming the ratio of the self- to air-broadened widths was 4.84 for all the lines and used an expression derived from eq. (1) to obtain their final values of  $b^\circ(\text{air})$ .

Yamada et al.(4) measured the air-broadened parameters of 271

lines of the (010)-(000) band of  $H_2^{16}O$  from 1211-2091  $\text{cm}^{-1}$  with a FTS at a resolution of 0.0039  $\text{cm}^{-1}$ . They obtained a co-added interferogram of over 300 scans with an absorption path length of 3-m. The sample contained a high partial pressure of  $H_2O$  which they estimated to be about 20 mbar. Their results were not corrected for the effects of self-broadening and they stated that the broadening coefficients,  $b^\circ$ , may be about 10% too large. A comparison of their results with the values from the present study show the agreement is not good for  $b^\circ$  for several of the narrower transitions even with corrections (due to self-broadening(1)) applied to their  $b^\circ$ 's. However, there is satisfactory agreement for the shift coefficients. In fact the relation,

$$|d^\circ(\text{this work}) - d^\circ(\text{Yamada et al.})| \leq \sqrt{\Delta d^\circ(\text{this work})^2 + \Delta d^\circ(\text{Yamada})^2} \quad (8)$$

holds for almost 50% of the 265 out of 271 lines that were compared.  $\Delta d^\circ$  is the uncertainty in  $d^\circ$ .

Valentin et al.(12) obtained the  $N_2$ -broadening shift coefficients,  $d^\circ$ , for 108 lines between 1842 and 1967  $\text{cm}^{-1}$  from measurements of three different spectra using a FTS with spectral resolution of 0.005  $\text{cm}^{-1}$ . A close inspection of the listing shows poor agreement , on the average, between the two studies in which the relationship given in eq. (8) is valid for only 22% of the compared values of  $d^\circ$ .

Table 7 compares the results from studies using tunable diode lasers with those of this study for air- and  $N_2$ -broadening

coefficients,  $b^\circ$ . The values given for line positions less than  $1070\text{ cm}^{-1}$  are from Eng and Mantz(9), and for lines located between  $1662$  and  $1669\text{ cm}^{-1}$  are from Mucha(10), and the remainder of the entries were taken from the work of Eng et al.(7). The overall comparison of the data given in the table is satisfactory. The narrowest lines given show that  $b^\circ < 0.01\text{ cm}^{-1}/\text{atm.}$  ( $1879.0194$ ,  $1932.8027$  and  $1879.8409\text{ cm}^{-1}$ ) from this work and also from Eng et al.(7) whereas none of the measurements given by Yamada et al.(4) for  $b^\circ$  were less than  $0.01\text{ cm}^{-1}/\text{atm.}$

## 6. DISCUSSION

Almost 1300 linewidths (HWHM) and pressure-induced line-shifts of  $\text{H}_2\text{O}$  broadened by air and  $\text{N}_2$  were accurately determined from spectral data with absorption path lengths ranging from  $25\text{ cm}$  to  $433\text{ m}$ . The experimental data included gas samples of  $\text{H}_2^{18}\text{O}$  broadened by  $\text{N}_2$  and the results were similar (for a given rotational transition) to the values obtained with normal water samples broadened by  $\text{N}_2$ . The measurements were corrected for the effects of self-broadening using the linewidth and frequency-shift results of Toth et al.(1). The linewidth data were grouped into "family" of rotational quantum numbers which revealed trends that from which smoothed values were derived from the air-broadened data. The same procedure was followed for the line-shift data however the plots showed large variations which were also graphed to obtain smoothed values for air-broadening. The results obtained in this study were compared to those of other relevant investigations(2,4,7,9,10).

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#### FIGURE CAPTIONS

FIGS. 1. and 2 Unapodized observed and synthetic spectra of  $\text{H}_2\text{O}$  broadened by air at a resolution of  $0.005 \text{ cm}^{-1}$  covering the completely overlapped doublets located at  $1879.019 \text{ cm}^{-1}$ . The absorption path length was 73 m. and the broadening pressure was 249 Torr. The observed spectrum was overlaid with the respective synthetic spectrum, and the residual plot, shown in the upper portion gives the percent differences between the observed and synthetic spectra. The synthetic spectrum was derived using a Voigt line profile function (fig 1.) which does not completely simulate the strong observed feature by noting, in the residual plot, the two spikes located near and on both sides of the center of the line. The effect is small (about 1%) and is due to collision narrowing. The derived linewidth (HWHM) of the absorption was  $b^o = 0.0064 \text{ cm}^{-1}/\text{atm}$ . For fig. 2, a Galatry line function was applied which produced an accurate fit to the observed spectrum with a derived  $b^o = 0.0072 \text{ cm}^{-1}/\text{atm}$ .

FIGS. 3. and 4 Unapodized observed and synthetic spectra of  $\text{H}_2\text{O}$  broadened by air at a resolution of  $0.005 \text{ cm}^{-1}$  covering two similar transitions located at  $1915.196$  and  $1915.270 \text{ cm}^{-1}$ . The absorption path length was 193 m. and the broadening pressure was 396 Torr. The observed spectrum was overlaid with the respective synthetic spectrum, and the residual plot, shown in the upper portion gives the percent differences between the observed and synthetic spectra. The synthetic spectrum was derived using a Voigt line profile function (fig 3.) which does not completely simulate the strong

observed features especially near the centers of the two lines. The effect is small (less than 1%) and is due to collision narrowing. The derived linewidths (HWHM) of the absorptions were  $b^o = 0.0094$  and  $0.0090 \text{ cm}^{-1}/\text{atm}$ . For fig. 4, a Galatry line function was applied which produced an accurate fit to the observed spectrum with derived linewidths of  $b^o = 0.0105$  and  $0.0104 \text{ cm}^{-1}/\text{atm}$ .

FIG. 5 Unapodized observed and synthetic spectra of  $\text{H}_2\text{O}$  broadened by air at a resolution of  $0.005 \text{ cm}^{-1}$  covering the completely overlapped doublets located at  $1879.019 \text{ cm}^{-1}$ . The absorption path length was 73 m. and the broadening pressure was 498 Torr. The observed spectrum was overlaid with the respective synthetic spectrum, and the residual plot, shown in the upper portion gives the percent differences between the observed and synthetic spectra. The synthetic spectrum was derived using a Voigt line profile function with the Gaussian contribution for a molecular weight of 100 which is much different than that of  $\text{H}_2^{16}\text{O}$  (18). This smaller contribution resulted in an excellent fit to the observed spectrum with a derived  $b^o = 0.072 \text{ cm}^{-1}/\text{atm}$ . which agrees with the value obtained using the Galatry function.

Fig. 6. Pressure induced frequency-shift coefficients of air-broadened  $\text{H}_2\text{O}$  as a function of  $|M|$ . The two curves (smoothed values) represent the "families" of rotational transitions:  $\Delta K_a = 1$ ,  $K_a'' = 0$  for the R-branch and  $\Delta K_a = -1$ ,  $K_a' = 0$  for the P-branch.

Table 1. Experimental Conditions

Path (m)		Sample pressures (Torr)	Temp.	Broadening	Freq.
	H <sub>2</sub> <sup>16</sup> O	Broadener	(K)	gas	Calib. <sup>a</sup>
73	1.05	249.0	296	room air	N <sub>2</sub> O
193	1.00	249.0	296	room air	N <sub>2</sub> O
433	0.934	249.1	296	room air	N <sub>2</sub> O
25	2.46	497.5	296	room air	N <sub>2</sub> O
73	2.23	497.8	296	room air	N <sub>2</sub> O
193	2.16	497.8	296	room air	N <sub>2</sub> O
433	2.16	497.9	296	room air	N <sub>2</sub> O
2.39	1.44*	305.9	296	N <sub>2</sub>	H <sub>2</sub> <sup>16</sup> O
2.39	1.92*	501.9	296	N <sub>2</sub>	H <sub>2</sub> <sup>16</sup> O
73	2.82	396.7	296	dry air	CO <sub>2</sub>
193	2.99	396.3	296	dry air	CO <sub>2</sub>
433	2.98	396.3	296	dry air	CO <sub>2</sub>
433	3.02	399.0	296	N <sub>2</sub>	CO <sub>2</sub>
193	3.20	398.8	296	N <sub>2</sub>	CO <sub>2</sub>
73	3.28	398.7	296	N <sub>2</sub>	CO <sub>2</sub>
25	3.42	398.6	296	N <sub>2</sub>	CO <sub>2</sub> , N <sub>2</sub> O
1.5	2.41	252.6	301	N <sub>2</sub>	H <sub>2</sub> <sup>16</sup> O, CO
1.5	2.42	349.3	301	N <sub>2</sub>	H <sub>2</sub> <sup>16</sup> O, CO
1.5	2.46	448.1	301	N <sub>2</sub>	H <sub>2</sub> <sup>16</sup> O, CO
1.5	2.49	548.5	301	N <sub>2</sub>	H <sub>2</sub> <sup>16</sup> O, CO
1.75	0.60	100.0	295	dry air	H <sub>2</sub> <sup>16</sup> O
1.75	0.60	150.0	295	dry air	H <sub>2</sub> <sup>16</sup> O
1.75	0.60	200.0	295	dry air	H <sub>2</sub> <sup>16</sup> O
1.5	2.40	252.0	301	dry air	H <sub>2</sub> <sup>16</sup> O, CO
1.5	2.43	347.6	301	dry air	H <sub>2</sub> <sup>16</sup> O, CO
1.5	2.49	447.7	301	dry air	H <sub>2</sub> <sup>16</sup> O, CO
1.5	2.52	568.1	301	dry air	H <sub>2</sub> <sup>16</sup> O, CO
0.25	1.30	74.6	295	dry air	H <sub>2</sub> <sup>16</sup> O
0.25	1.30	99.8	295	dry air	H <sub>2</sub> <sup>16</sup> O
0.25	1.30	149.5	295	dry air	H <sub>2</sub> <sup>16</sup> O
0.25	1.30	199.5	295	dry air	H <sub>2</sub> <sup>16</sup> O
0.25	2.80	247.9	301	N <sub>2</sub>	H <sub>2</sub> <sup>16</sup> O
0.25	2.78	352.1	301	N <sub>2</sub>	H <sub>2</sub> <sup>16</sup> O
0.25	2.82	454.5	301	N <sub>2</sub>	H <sub>2</sub> <sup>16</sup> O
0.25	2.84	547.8	301	N <sub>2</sub>	H <sub>2</sub> <sup>16</sup> O
0.25	2.70	275.2	301	dry air	H <sub>2</sub> <sup>16</sup> O
0.25	2.75	349.7	301	dry air	H <sub>2</sub> <sup>16</sup> O
0.25	2.80	468.7	301	dry air	H <sub>2</sub> <sup>16</sup> O
0.25	2.83	546.6	301	dry air	H <sub>2</sub> <sup>16</sup> O

(a). Low pressure absorptions of the molecule(s) listed of which the line center frequencies were accurately measured in the spectra and used for frequency calibration.

\* the water vapor sample was 98% H<sub>2</sub><sup>18</sup>O.

The dry air samples contained about 0.08ppm N<sub>2</sub>O and 0.8ppm CO<sub>2</sub> and no detectable CH<sub>4</sub> as determined from the long path length spectra.

The N<sub>2</sub> samples contained no detectable N<sub>2</sub>O, CO<sub>2</sub> and CH<sub>4</sub> as determined from the long path length spectra.

Table 2. Line positions, strengths, air and N<sub>2</sub>-broadened width coefficients, (HWHM) b°, and pressure-induced frequency shift coefficients, d°, for the (010)-(000) band of H<sub>2</sub><sup>16</sup>O.

computed position	un	upper J K <sub>a</sub> K <sub>c</sub>	lower J K <sub>a</sub> K <sub>c</sub>	observed strength	ts	(o-c) †	-----air-----	----N <sub>2</sub> ----	-----air-----	----N <sub>2</sub> ----		
							b°(sm)	b°(obs.)	b°(obs.)	d°(sm)	d°(obs.)	d°(obs.)
897.69402	5	12 1 12	13 2 11	3.01E-05	2	-1.0	374.	380. ( 20. )	430. ( 40. )	-22.	-28. ( 43. )	-34. ( 61. )
953.36743	3	11 0 11	12 3 10	1.19E-04	1	.0	405.	406. ( 23. )	459. ( 17. )	-46.	-46. ( 5. )	-60. ( 6. )
955.68697	6	11 1 11	12 2 10	4.01E-05	3	-.8	418.	402. ( 33. )	482. ( 8. )	1.	1. ( 8. )	11. ( 33. )
998.80957	3	8 3 6	9 6 3	5.42E-05	3	-.4	635.	637. ( 22. )	731. ( 27. )	-34.	-34. ( 4. )	-20. ( 23. )
1010.02820	5	10 0 10	11 3 9	1.41E-04	2	-1.4	468.	465. ( 3. )	525. ( 5. )	-64.	-64. ( 4. )	-68. ( 4. )
1010.81330	2	11 1 10	12 4 9	1.31E-04	2	-1.1	437.	425. ( 7. )	490. ( 15. )	-147.	-147. ( 3. )	-160. ( 8. )
1014.47521	4	10 1 10	11 2 9	4.33E-04	2	-2.8	492.	502. ( 10. )	562. ( 11. )	26.	26. ( 4. )	21. ( 5. )
1017.86846	2	8 2 7	9 5 4	1.52E-04	3	-2.4	709.	699. ( 17. )	798. ( 15. )	-80.	-80. ( 13. )	-107. ( 22. )
1029.69739	5	9 3 6	10 6 5	5.65E-05	1	.6	740.	786. ( 2. )	820. ( 90. )	12.	12. ( 21. )	51. ( 21. )
1030.54454	2	11 2 10	12 3 9	5.25E-05	2	-.9	630.	648. ( 14. )	666. ( 67. )	1.	1. ( 13. )	-27. ( 14. )
1049.31430	3	7 1 7	8 4 4	9.38E-05	1	.1	838.	890. ( 40. )	962. ( 14. )	44.	44. ( 6. )	66. ( 1. )
1055.51771	2	6 3 4	7 6 1	8.68E-05	2	-.6	691.	690. ( 20. )	773. ( 3. )	-6.	-6. ( 7. )	6. ( 16. )
1060.11640	3	10 1 9	11 4 8	1.59E-04	2	-2.4	515.	529. ( 10. )	612. ( 4. )	-162.	-162. ( 8. )	-188. ( 11. )
1062.62835	3	7 2 6	8 5 3	1.16E-04	1	-.4	702.	693. ( 36. )	792. ( 25. )	-86.	-86. ( 11. )	-86. ( 5. )
1066.15458	2	9 0 9	10 3 8	1.42E-03	3	1.0	542.	543. ( 9. )	610. ( 10. )	-72.	-72. ( 4. )	-80. ( 1. )
1072.61352	7	10 2 8	11 5 7	7.57E-05	5	-1.4	646.	669. ( 50. )	879. ( 43. )	-120.	-120. ( 48. )	-125. ( 0. )
1074.40703	2	9 1 9	10 2 8	4.92E-04	2	-2.2	589.	585. ( 15. )	663. ( 22. )	25.	25. ( 5. )	38. ( 6. )
1091.20494	3	10 2 9	11 3 8	6.80E-04	2	.8	665.	632. ( 8. )	715. ( 9. )	35.	35. ( 8. )	31. ( 3. )
1099.67926	3	9 2 7	10 5 6	5.30E-04	3	-.3	722.	761. ( 13. )	877. ( 9. )	-130.	-130. ( 3. )	-149. ( 1. )
1101.45060	4	6 2 5	7 5 2	5.38E-04	2	-1.5	713.	718. ( 9. )	829. ( 5. )	-60.	-60. ( 5. )	-71. ( 5. )
1106.74393	3	9 1 8	10 4 7	1.56E-03	2	-.1	600.	616. ( 9. )	710. ( 9. )	-175.	-175. ( 4. )	-202. ( 5. )
1111.51619	3	6 1 6	7 4 3	8.33E-04	2	-.4	838.	846. ( 31. )	922. ( 15. )	-60.	-60. ( 13. )	-65. ( 6. )
1120.83213	4	8 2 6	9 5 5	3.01E-04	2	-1.7	783.	802. ( 13. )	925. ( 15. )	-86.	-86. ( 9. )	-109. ( 8. )
1121.23200	2	8 0 8	9 3 7	1.36E-03	1	-2.0	625.	624. ( 5. )	696. ( 3. )	-85.	-85. ( 4. )	-97. ( 5. )
1135.52000	1	5 2 4	6 5 1	1.83E-04	2	-2.3	750.	720. ( 30. )	840. ( 60. )	-50.	-50. ( 12. )	-46. ( 19. )
1135.74531	1	8 1 8	9 2 7	4.76E-03	2	-.4	699.	705. ( 15. )	770. ( 13. )	16.	16. ( 4. )	19. ( 3. )
1137.42577	2	7 2 5	8 5 4	1.17E-03	2	-1.7	825.	762. ( 16. )	864. ( 5. )	-30.	-30. ( 3. )	-25. ( 3. )
1149.46917	2	8 1 7	9 4 6	1.37E-03	1	-.7	686.	713. ( 12. )	823. ( 7. )	-141.	-141. ( 7. )	-160. ( 4. )
1151.54395	2	6 2 4	7 5 3	3.84E-04	2	-1.8	845.	835. ( 21. )	937. ( 10. )	-10.	-10. ( 4. )	10. ( 6. )
1152.44411	4	9 2 8	10 3 7	9.22E-04	2	.5	724.	716. ( 4. )	800. ( 23. )	-19.	-19. ( 3. )	-27. ( 2. )
1165.04886	3	5 1 5	6 4 2	5.31E-04	2	-1.0	849.	836. ( 27. )	946. ( 8. )	-57.	-57. ( 5. )	-66. ( 2. )
1165.36993	3	5 2 3	6 5 2	8.52E-04	2	-.1	845.	845. ( 13. )	962. ( 16. )	-31.	-31. ( 4. )	-30. ( 10. )
1165.94002	2	4 2 3	5 5 0	3.15E-04	1	-.2	822.	817. ( 9. )	927. ( 10. )	-31.	-31. ( 8. )	-27. ( 5. )
1173.71819	7	10 3 8	11 4 7	1.13E-03	2	1.0	809.	772. ( 7. )	877. ( 8. )	-92.	-92. ( 5. )	-99. ( 9. )
1174.52695	3	7 0 7	8 3 6	1.07E-02	2	-2.4	713.	721. ( 6. )	807. ( 6. )	-84.	-84. ( 2. )	-99. ( 1. )
1180.82807	2	4 2 2	5 5 1	1.26E-04	1	.7	829.	852. ( 15. )	955. ( 7. )	-28.	-28. ( 21. )	-23. ( 15. )
1187.02165	4	7 1 6	8 4 5	8.65E-03	2	1.2	766.	804. ( 5. )	900. ( 5. )	-105.	-105. ( 4. )	-117. ( 4. )
1195.34395	7	12 6 7	13 7 6	3.76E-05	4	-.7	330.	320. ( 20. )	368. ( 5. )	-34.	-34. ( 7. )	-24. ( 4. )
1198.17815	3	7 1 7	8 2 6	4.80E-03	3	.3	805.	803. ( 12. )	887. ( 8. )	-1.	-1. ( 2. )	-3. ( 1. )
1201.46258	7	12 7 6	13 8 5	1.85E-05	4	2.8	390.	360. ( 17. )	410. ( 30. )	-33.	-33. ( 15. )	-17. ( 40. )
1211.25564	2	4 1 4	5 4 1	1.93E-03	1	1.0	876.	908. ( 14. )	993. ( 19. )	-52.	-52. ( 7. )	-57. ( 4. )
1212.24672	2	8 2 7	9 3 6	1.10E-02	1	1.3	788.	815. ( 13. )	910. ( 7. )	-54.	-54. ( 1. )	-65. ( 1. )
1213.00716	7	11 5 7	12 6 6	1.06E-04	2	2.5	506.	513. ( 1. )	573. ( 27. )	-42.	-42. ( 10. )	-61. ( 9. )
1214.95827	1	8 1 8	8 4 5	1.90E-04	2	-.9	736.	768. ( 24. )	857. ( 18. )	-62.	-62. ( 8. )	-64. ( 14. )
1218.51983	2	6 1 5	7 4 4	4.30E-03	1	1.5	833.	830. ( 13. )	924. ( 7. )	-64.	-64. ( 4. )	-69. ( 4. )
1219.14720	7	11 6 6	12 7 5	6.15E-05	2	2.2	363.	368. ( 12. )	419. ( 10. )	-32.	-32. ( 8. )	-23. ( 16. )
1220.34465	6	11 6 5	12 7 6	1.84E-04	2	1.7	363.	384. ( 4. )	437. ( 8. )	-5.	-5. ( 4. )	2. ( 4. )
1224.89117	12	11 7 4	12 8 5	8.66E-05	2	2.5	376.	394. ( 14. )	516. ( 103. )	-37.	-37. ( 3. )	-71. ( 71. )
1224.97772	3	9 3 7	10 4 6	1.82E-03	2	1.0	841.	808. ( 19. )	913. ( 42. )	-64.	-64. ( 6. )	-63. ( 13. )
1225.08626	2	6 0 6	7 3 5	8.46E-03	2	1.6	797.	789. ( 5. )	884. ( 9. )	-75.	-75. ( 3. )	-81. ( 3. )
1225.55127	6	10 4 7	11 5 6	1.72E-03	2	1.7	685.	681. ( 23. )	765. ( 4. )	-126.	-126. ( 6. )	-134. ( 1. )
1226.10364	3	11 5 6	12 6 7	3.27E-04	2	1.8	521.	520. ( 15. )	586. ( 1. )	104.	104. ( 3. )	139. ( 4. )
1229.36372	2	9 0 9	9 3 6	1.72E-04	2	-.7	803.	814. ( 12. )	915. ( 20. )	-56.	-56. ( 18. )	-61. ( 12. )
*1233.28658	10	11 8 3	12 9 4	4.85E-05	2	5.2	296.	295. ( 19. )	344. ( 32. )	-37.	-41. ( 13. )	-51. ( 6. )
*1235.20405	58	17 0 17	18 1 18	7.75E-06	2	-2.4	58.	57. ( 4. )	59. ( 9. )	-33.	-33. ( 2. )	-33. ( 5. )
1236.75656	5	11 1 10	11 4 7	3.67E-05	2	3.1	809.	790. ( 50. )	834. ( 40. )	-71.	-71. ( 48. )	-53. ( 79. )
1239.21909	4	10 5 6	11 6 5	1.37E-03	2	.5	474.	460. ( 7. )	524. ( 11. )	-48.	-48. ( 2. )	-50. ( 2. )
1242.79930	5	10 6 5	11 7 4	7.68E-04	2	1.1	392.	385. ( 3. )	439. ( 4. )	-21.	-21. ( 2. )	-17. ( 2. )
1243.19053	5	10 6 4	11 7 5	2.56E-04	2	1.0	392.	398. ( 6. )	452. ( 7. )	-17.	-17. ( 6. )	-12. ( 3. )
1244.13823	2	5 1 4	6 4 3	1.28E-02	1	.8	879.	865. ( 2. )	961. ( 7. )	-55.	-55. ( 2. )	-56. ( 4. )
1244.80298	3	10 5 5	11 6 6	4.64E-04	2	.8	500.	502. ( 4. )	568. ( 6. )	50.	50. ( 1. )	73. ( 3. )
1246.68076	2	7 3 4	7 6 1	4.57E-05	1	-.8	812.	812. ( 20. )	0. ( 0. )	13.	13. ( 7. )	-6. ( 27. )
1248.44618	5	10 7 4	11 8 3	3.58E-04	2	1.5	351.	344. ( 4. )	385. ( 10. )	-29.	-29. ( 1. )	-38. ( 19. )
1248.46321	7	10 7 3	11 8 4	1.18E-04	2	.4	351.	329. ( 1. )	386. ( 39. )	-22.	-22. ( 10. )	-41. ( 21. )
1251.34953	1	3 1 3	4 4 0	3.79E-04	1	.6	925.	910. ( 13. )	995. ( 14. )	-57.	-57. ( 5. )	-51. ( 3. )
1253.34597	3	7 1 7	7 4 4	1.67E-04	2	-.6	773.	779. ( 46. )	882. ( 76. )	-37.	-37. ( 15. )	-49. ( 24. )
*1255.96163	22	16 1 16	17 0 17	3.85E-05	2	-2.6	59.	58. ( 2. )	62. ( 3. )	-32.	-32. ( 3. )	-30. ( 1. )
*1257.08761	10	10 8 3	11 9 2	1.92E-04	2	-.1	273.	275. ( 9. )	301. ( 16. )	-28.	-25. ( 6. )	-31. ( 3. )
1258.61761	5	9 4 6	10 5 5	2.43E-03	2	1.0	652.	635. ( 7. )	730. ( 23. )	-95.	-95. ( 2. )	-104. ( 2. )
1258.89324	3	7 2 6	7 5 3	9.70E-05	3	-.9	695.	674. ( 30. )	767. ( 40. )	-92.	-92. ( 10. )	-113. ( 71. )
1260.34347	3	6 1 6	7 2 5	4.16E-02	2	-1.0	891.	914. ( 10. )	993. ( 20. )	-35.	-38. ( 36. )	-22. ( 11. )
*1263.50285	33	17 0 17	17 1 16	7.10E-06	15	-2.0	94.	92. ( 10. )	102. ( 15. )	-76.	-76. ( 1. )	-62. ( 14. )

Table 2. continued

computed position	un	upper J	K <sub>a</sub>	K <sub>c</sub>	lower J	K <sub>a</sub>	K <sub>c</sub>	observed strength	%s	(o-c)%	air b°(sm)	air b°(obs.)	N <sub>2</sub> b°(obs.)	air d°(sm)	air d°(obs.)	N <sub>2</sub> d°(obs.)
1264.01392	5	9	5	5	10	6	4	1.75E-03	2	.8	462.	461.( 8.)	519.( 7.)	-19.	-19.( 1.)	-17.( 4.)
1265.35524	2	4	1	3	5	4	2	2.73E-03	1	1.6	900.	879.( 20.)	974.( 14.)	-54.	-54.( 1.)	-47.( 1.)
1266.07298	5	9	5	4	10	6	5	5.25E-03	1	.3	493.	494.( 4.)	557.( 5.)	29.	29.( 3.)	44.( 4.)
1266.56110	4	9	6	4	10	7	3	9.44E-04	2	.0	408.	393.( 18.)	446.( 4.)	-15.	-15.( 8.)	-14.( 2.)
1266.66809	9	9	6	3	10	7	4	2.84E-03	1	.3	408.	396.( 5.)	450.( 6.)	-20.	-19.( 3.)	-16.( 0.)
1267.95308	6	10	4	6	11	5	7	6.84E-04	2	1.6	691.	691.( 3.)	800.( 9.)	79.	79.( 3.)	109.( 10.)
*1268.11481	8	10	9	2	11	10	1	6.80E-05	4	-3.5	206.	202.( 13.)	222.( 8.)	-37.	-37.( 10.)	-29.( 6.)
1268.38222	3	7	2	6	8	3	5	1.36E-02	2	-.9	843.	870.( 15.)	978.( 10.)	-36.	-36.( 6.)	-36.( 3.)
1269.95724	3	8	3	6	9	4	5	2.36E-02	4	1.9	825.	841.( 10.)	944.( 31.)	-54.	-54.( 4.)	-63.( 1.)
1271.78782	3	5	0	5	6	3	4	4.55E-02	1	-2.1	871.	870.( 50.)	930.( 40.)	-62.	-62.( 4.)	-68.( 11.)
1272.34362	5	9	7	2	10	8	3	1.32E-03	2	1.0	321.	309.( 26.)	357.( 17.)	-9.	-9.( 6.)	-37.( 4.)
1272.68731	4	6	2	5	6	5	2	3.08E-04	1	.2	740.	710.( 35.)	850.( 30.)	-49.	-49.( 17.)	-63.( 5.)
1272.96063	15	16	2	15	17	1	16	5.90E-06	10	7.8	59.	55.( 2.)	52.( 15.)	-23.	-23.( 9.)	-26.( 13.)
*1276.62619	13	15	0	15	16	1	16	1.86E-04	3	3.4	64.	68.( 4.)	72.( 4.)	-32.	-32.( 2.)	-30.( 2.)
1280.04751	4	9	4	5	10	5	6	7.82E-03	1	.4	698.	694.( 7.)	796.( 10.)	86.	86.( 4.)	110.( 2.)
*1280.99944	18	10	10	1	11	11	0	2.44E-05	2	5.2	132.	132.( 13.)	161.( 16.)	-14.	-14.( 7.)	-43.( 22.)
*1281.16125	5	9	8	1	10	9	2	7.07E-04	2	-.3	236.	235.( 10.)	265.( 15.)	-19.	-19.( 5.)	-20.( 1.)
1282.07963	1	5	2	4	5	5	1	5.60E-05	3	2.9	930.	946.( 28.)	913.( 93.)	-27.	-27.( 3.)	-53.( 28.)
1284.30580	5	3	1	2	4	4	1	2.79E-03	1	1.3	893.	903.( 8.)	992.( 5.)	-65.	-65.( 4.)	-63.( 6.)
1284.92718	11	16	1	16	16	2	15	2.70E-05	2	4.1	109.	105.( 6.)	0.( 0.)	-25.	-25.( 2.)	-33.( 33.)
1286.02851	3	6	1	6	6	4	3	9.36E-04	2	-1.0	810.	819.( 12.)	911.( 11.)	-55.	-55.( 6.)	-55.( 5.)
1287.40006	2	8	4	5	9	5	4	2.57E-02	3	-1.1	616.	598.( 15.)	693.( 28.)	-64.	-64.( 10.)	-63.( 1.)
1288.24992	2	8	5	4	9	6	3	1.74E-02	2	-.4	459.	476.( 11.)	536.( 22.)	-16.	-16.( 2.)	-12.( 5.)
1288.88653	4	8	5	3	9	6	4	5.84E-03	2	.2	488.	491.( 9.)	549.( 20.)	9.	9.( 0.)	19.( 1.)
1290.53591	5	8	6	3	9	7	2	9.48E-03	2	1.4	400.	390.( 30.)	434.( 17.)	-13.	-13.( 11.)	-14.( 1.)
1290.55888	5	8	6	2	9	7	3	3.07E-03	3	-1.5	400.	400.( 30.)	425.( 35.)	-14.	-14.( 3.)	-10.( 5.)
1290.71600	6	15	1	14	16	2	15	2.95E-05	4	7.2	96.	95.( 1.)	98.( 7.)	-35.	-35.( 3.)	-30.( 4.)
1290.76761	5	15	2	14	16	1	15	9.50E-06	3	3.7	77.	86.( 2.)	100.( 6.)	-27.	-27.( 9.)	-33.( 13.)
*1292.37163	10	9	9	0	10	10	1	2.65E-04	5	2.5	156.	152.( 4.)	175.( 0.)	-43.	-43.( 3.)	-45.( 1.)
1295.52125	8	15	2	13	16	3	14	7.11E-06	3	-6.7	136.	142.( 15.)	155.( 31.)	-63.	-63.( 17.)	-76.( 76.)
*1296.49006	6	8	7	2	9	8	1	5.75E-03	1	.3	288.	280.( 15.)	329.( 20.)	-17.	-17.( 0.)	-12.( 1.)
1296.70935	5	8	4	4	9	5	5	9.07E-03	1	1.8	679.	686.( 33.)	769.( 25.)	62.	62.( 2.)	83.( 4.)
1297.18372	5	14	1	14	15	0	15	5.60E-04	2	.0	77.	78.( 7.)	85.( 5.)	-40.	-40.( 1.)	-36.( 2.)
*1305.48838	7	8	8	1	9	9	0	2.25E-03	3	-3.3	193.	185.( 19.)	202.( 7.)	-48.	-47.( 23.)	-45.( 2.)
1306.30272	7	15	0	15	15	1	14	1.16E-04	4	2.6	136.	140.( 14.)	161.( 7.)	-44.	-44.( 22.)	-45.( 9.)
1308.17886	3	7	3	5	8	4	4	2.84E-02	2	1.5	785.	788.( 20.)	912.( 43.)	-55.	-55.( 9.)	-61.( 3.)
1308.56305	5	14	2	13	15	1	14	1.33E-04	2	5.6	99.	100.( 2.)	110.( 2.)	-38.	-38.( 1.)	-36.( 0.)
1310.80855	5	14	2	12	15	3	13	1.22E-05	2	-1.3	169.	160.( 16.)	181.( 22.)	-80.	-95.( 48.)	-94.( 14.)
1311.89238	3	5	2	3	5	5	0	2.55E-04	2	1.0	883.	880.( 8.)	980.( 17.)	-27.	-27.( 20.)	-30.( 7.)
1312.39954	3	7	5	3	8	6	2	1.70E-02	2	-1.1	453.	455.( 12.)	515.( 20.)	-5.	-5.( 5.)	2.( 8.)
1312.55566	3	7	5	2	8	6	3	5.17E-02	2	.2	473.	457.( 16.)	528.( 25.)	2.	2.( 2.)	9.( 4.)
1313.48306	5	4	0	4	5	3	3	2.16E-02	3	2.0	927.	940.( 35.)	1033.( 105.)	-49.	-49.( 8.)	-36.( 40.)
1313.59641	2	7	4	4	8	5	3	2.60E-02	3	-2.4	582.	575.( 7.)	647.( 20.)	-26.	-26.( 4.)	-26.( 5.)
*1314.74340	2	7	6	1	8	7	2	3.60E-02	5	-1.5	362.	399.( 40.)	424.( 44.)	-29.	-29.( 15.)	-23.( 2.)
1316.97240	2	7	4	3	8	5	4	7.95E-02	2	-1.4	643.	640.( 20.)	720.( 12.)	40.	40.( 3.)	59.( 5.)
1317.61047	3	13	0	13	14	1	14	2.12E-03	2	.1	92.	93.( 9.)	106.( 3.)	-9.	-9.( 10.)	1.( 1.)
1318.92946	4	6	2	5	7	3	4	1.49E-01	3	2.6	875.	867.( 17.)	968.( 12.)	-16.	-16.( 2.)	-14.( 2.)
1320.05555	3	5	1	5	6	2	4	4.15E-02	2	2.2	945.	930.( 30.)	1033.( 59.)	-17.	-17.( 3.)	-15.( 6.)
*1320.86877	6	7	7	0	8	8	1	1.67E-02	2	-.4	257.	255.( 20.)	274.( 16.)	-50.	-50.( 14.)	-46.( 1.)
1322.55795	2	6	2	4	6	5	1	2.30E-04	2	1.1	837.	834.( 12.)	950.( 12.)	-8.	-8.( 5.)	-5.( 3.)
1323.33443	3	9	3	6	10	4	7	1.09E-02	1	1.2	739.	729.( 18.)	828.( 4.)	56.	56.( 2.)	77.( 1.)
1325.60509	5	13	2	11	14	3	12	1.60E-04	2	-2.5	221.	214.( 15.)	234.( 3.)	-95.	-95.( 4.)	-109.( 4.)
1326.13483	5	13	1	12	14	2	13	5.45E-04	3	4.1	119.	123.( 4.)	133.( 5.)	-41.	-41.( 0.)	-40.( 1.)
1326.33140	4	13	2	12	14	1	13	1.83E-04	3	4.9	129.	126.( 5.)	138.( 5.)	-37.	-37.( 1.)	-36.( 1.)
1327.57111	5	14	1	14	14	2	13	4.41E-04	2	-2.3	161.	173.( 4.)	192.( 5.)	-48.	-48.( 2.)	-52.( 2.)
1327.55896	10	14	0	14	14	1	13	1.48E-04	1	-1.6	166.	173.( 7.)	195.( 6.)	-46.	-46.( 4.)	-46.( 1.)
1327.84456	3	9	1	8	9	4	5	1.22E-03	2	2.2	783.	801.( 3.)	902.( 13.)	-38.	-38.( 3.)	-33.( 6.)
1328.83830	6	13	3	11	14	2	12	5.39E-05	2	-1.2	206.	201.( 5.)	214.( 7.)	-9.	-9.( 4.)	4.( 2.)
1329.90473	5	8	3	5	9	4	6	1.15E-02	1	1.1	780.	804.( 27.)	906.( 5.)	61.	61.( 5.)	79.( 1.)
1333.48911	2	4	1	4	4	4	1	6.95E-04	2	.2	902.	919.( 30.)	986.( 4.)	-56.	-56.( 3.)	-56.( 7.)
1336.66273	2	6	5	2	7	6	1	1.35E-01	3	.1	435.	420.( 9.)	491.( 6.)	14.	14.( 12.)	15.( 4.)
1336.68992	2	6	5	1	7	6	2	4.50E-02	4	-.1	437.	452.( 10.)	505.( 7.)	24.	24.( 6.)	36.( 6.)
1337.90873	5	12	1	12	13	0	13	7.37E-03	2	.9	120.	119.( 8.)	125.( 6.)	-28.	-28.( 5.)	-18.( 4.)
1338.54602	3	6	4	3	7	5	2	2.08E-01	1	-2.4	552.	565.( 4.)	622.( 17.)	4.	4.( 7.)	6.( 2.)
*1339.14848	3	6	6	1	7	7	0	1.00E-01	3	4.8	296.	284.( 10.)	314.( 25.)	-47.	-47.( 2.)	-46.( 3.)
1339.51881	2	6	4	2	7	5	3	7.08E-02	1	-.5	601.	595.( 6.)	687.( 12.)	31.	31.( 4.)	43.( 3.)
1340.16673	2	7	3	4	8	4	5	1.00E-01	4	-.5	799.	817.( 6.)	907.( 8.)	36.	36.( 2.)	54.( 3.)
1340.47511	2	6	3	4	7	4	3	2.55E-01	1	1.4	739.	749.( 8.)	841.( 10.)	-59.	-59.( 2.)	-63.( 4.)
1341.10070	3	9	2	7	9	5	4	7.18E-04	1	-.9	760.	755.( 27.)	824.( 20.)	-110.	-110.( 6.)	-111.( 16.)
1343.67834	8	12	1	11	13	2	12	6.79E-04	2	3.1	155.	151.( 4.)	167.( 8.)	-48.	-48.( 2.)	-49.( 1.)
1344.06892	3	12	2	11	13	1	12	2.03E-03	1	2.8	168.	164.( 9.)	172.( 5.)	-32.	-32.( 2.)	-31.( 3.)

Table 2. continued

computed position	un	upper		lower		observed strength	ts	air		N <sub>2</sub>		air		N <sub>2</sub>		
		J	K <sub>a</sub>	K <sub>c</sub>	J	K <sub>a</sub>	K <sub>c</sub>	b°(sm)	b°(obs.)	b°(obs.)	d°(sm)	d°(obs.)	d°(obs.)			
1352.34871	3	11	2	9	12	3	10	2.31E-03	1	-2.0	388.	405.( 11.)	464.( 15.)	-160.	-160.( 1.)	-181.( 2.)
1352.89707	7	16	2	15	16	3	14	1.15E-05	4	-3.	116.	111.( 6.)	134.( 15.)	-53.	-53.( 2.)	-67.( 9.)
1354.84567	3	6	3	3	7	4	4	8.83E-02	2	-1.4	793.	773.( 21.)	883.( 9.)	37.	37.( 8.)	43.( 3.)
1356.15549	6	12	4	9	13	3	10	1.93E-04	2	-7.9	470.	464.( 5.)	545.( 20.)	182.	180.( 17.)	216.( 5.)
1358.02658	3	11	0	11	12	1	12	2.26E-02	2	-1.3	153.	145.( 4.)	167.( 9.)	-24.	-24.( 4.)	-18.( 4.)
1358.04989	5	11	1	12	12	0	12	7.72E-03	2	1.2	156.	146.( 8.)	159.( 12.)	-27.	-27.( 10.)	-20.( 6.)
1358.57848	2	8	1	7	8	4	4	1.42E-03	2	-6	790.	791.( 12.)	881.( 12.)	-64.	-64.( 5.)	-59.( 4.)
1361.08511	3	5	5	0	6	6	1	3.19E-01	3	1.7	375.	371.( 32.)	420.( 20.)	-24.	-24.( 16.)	-17.( 21.)
1361.79623	3	11	2	10	12	1	11	2.31E-03	1	2.7	218.	210.( 7.)	230.( 16.)	-27.	-27.( 3.)	-25.( 3.)
1362.60374	1	5	2	4	6	3	3	1.53E-01	1	2.0	881.	862.( 15.)	945.( 21.)	-16.	-16.( 6.)	-12.( 4.)
1363.06264	3	5	4	2	6	5	1	1.57E-01	0	-5.7	531.	551.( 12.)	633.( 12.)	14.	14.( 3.)	28.( 8.)
1363.26375	2	5	4	1	6	5	2	4.78E-01	1	-4.3	560.	566.( 6.)	648.( 6.)	25.	25.( 2.)	38.( 4.)
1368.62750	3	5	3	3	6	4	2	2.10E-01	1	-4	699.	688.( 5.)	805.( 13.)	-32.	-32.( 5.)	-33.( 3.)
1369.82768	4	12	1	12	12	2	11	5.25E-03	2	-4.4	245.	249.( 14.)	268.( 6.)	-34.	-34.( 4.)	-36.( 1.)
1369.95301	3	12	0	12	12	1	11	1.76E-03	2	-4.0	254.	247.( 9.)	281.( 10.)	-28.	-28.( 3.)	-26.( 3.)
1370.57365	5	15	2	14	15	3	13	1.85E-05	2	.2	149.	155.( 5.)	165.( 10.)	-52.	-57.( 57.)	-52.( 10.)
1370.83543	5	15	1	14	15	2	13	5.65E-05	2	1.7	163.	172.( 10.)	181.( 9.)	-29.	-29.( 4.)	-26.( 11.)
1372.26982	3	9	2	7	10	3	8	2.18E-02	2	-1.4	617.	644.( 27.)	737.( 18.)	-118.	-118.( 8.)	-130.( 11.)
1373.76950	2	5	3	2	6	4	3	6.42E-01	0	.3	763.	755.( 6.)	856.( 7.)	28.	28.( 3.)	41.( 3.)
1375.08613	2	4	1	4	5	2	3	3.54E-01	1	2.3	965.	953.( 7.)	1052.( 8.)	-20.	-20.( 4.)	-22.( 2.)
1377.97923	4	10	0	10	11	1	11	2.15E-02	1	-1.0	203.	199.( 8.)	224.( 8.)	-17.	-17.( 1.)	-18.( 4.)
1378.02963	5	10	1	10	11	0	11	6.30E-02	3	-3.3	205.	207.( 4.)	226.( 3.)	-24.	-24.( 2.)	-20.( 4.)
1378.49308	4	7	1	6	7	4	3	9.50E-03	2	.2	807.	820.( 9.)	944.( 7.)	-77.	-77.( 6.)	-80.( 3.)
1379.74521	2	2	0	2	3	3	1	6.91E-03	2	2.2	965.	971.( 10.)	1065.( 9.)	-76.	-76.( 5.)	-80.( 6.)
1380.23159	2	6	0	6	6	3	3	5.22E-03	2	-.5	891.	917.( 24.)	976.( 6.)	-19.	-19.( 3.)	-21.( 2.)
1381.53131	2	11	4	8	12	3	9	2.23E-04	1	-7.9	573.	603.( 20.)	713.( 15.)	152.	154.( 11.)	201.( 23.)
1382.06197	5	10	3	8	11	2	9	7.10E-03	2	-3.8	460.	469.( 11.)	520.( 15.)	103.	103.( 6.)	131.( 4.)
1386.47659	2	7	2	5	8	3	6	1.43E-01	2	.5	811.	777.( 8.)	870.( 9.)	-10.	-10.( 2.)	-9.( 7.)
1387.52290	2	4	4	1	5	5	0	1.01E+00	5	-2.4	520.	506.( 6.)	565.( 4.)	18.	18.( 9.)	8.( 4.)
1387.54560	3	4	4	0	5	5	1	3.54E-01	5	2.6	527.	525.( 25.)	593.( 10.)	20.	18.( 9.)	-15.( 31.)
1388.34834	4	14	2	13	14	3	12	2.46E-04	2	.9	190.	202.( 10.)	235.( 25.)	-52.	-52.( 4.)	-46.( 23.)
1388.48354	2	6	1	5	6	4	2	4.17E-03	1	1.0	832.	840.( 15.)	931.( 30.)	-68.	-68.( 5.)	-60.( 10.)
1388.86404	4	14	1	13	14	2	12	8.26E-05	2	1.2	192.	186.( 7.)	215.( 22.)	-31.	-31.( 6.)	-41.( 21.)
1390.52185	2	5	1	4	5	4	1	8.95E-03	2	.6	864.	867.( 7.)	950.( 10.)	-54.	-54.( 3.)	-54.( 2.)
1390.75831	5	11	1	11	11	2	10	5.36E-03	1	-3.9	301.	299.( 3.)	323.( 7.)	-29.	-29.( 1.)	-30.( 1.)
1391.02642	3	11	0	11	11	1	10	1.58E-02	2	-5.8	314.	302.( 14.)	333.( 7.)	-13.	-13.( 2.)	-9.( 3.)
1394.47451	3	4	3	2	5	4	1	1.35E+00	1	1.1	674.	686.( 10.)	0.( 0.)	-1.	-1.( 4.)	0.( 0.)
1395.80258	1	4	3	1	5	4	2	4.40E-01	3	-1.6	714.	717.( 7.)	812.( 10.)	28.	28.( 2.)	40.( 3.)
1397.57543	5	9	2	8	10	1	9	1.92E-02	2	-.1	363.	361.( 4.)	402.( 4.)	13.	13.( 6.)	23.( 1.)
1397.73295	2	9	0	9	10	1	10	1.67E-01	1	-.5	269.	274.( 6.)	303.( 3.)	-24.	-24.( 5.)	-20.( 3.)
1397.84345	3	9	1	9	10	0	10	5.50E-02	1	-1.7	270.	275.( 2.)	303.( 5.)	-23.	-23.( 1.)	-19.( 2.)
1399.20425	2	4	2	3	5	3	2	1.15E+00	1	-.4	864.	858.( 5.)	966.( 5.)	-37.	-37.( 2.)	-37.( 3.)
1403.46215	2	9	3	7	10	2	8	6.61E-03	1	-.7	574.	603.( 12.)	673.( 8.)	111.	111.( 3.)	136.( 1.)
1404.98997	3	5	2	3	6	3	4	6.89E-01	1	-2.7	876.	869.( 10.)	966.( 12.)	1.	1.( 3.)	11.( 3.)
1406.15066	3	13	2	12	13	3	11	3.26E-04	2	2.0	239.	233.( 5.)	255.( 5.)	-51.	-51.( 5.)	-61.( 4.)
1407.16411	4	13	1	12	13	2	11	9.92E-04	2	2.6	240.	244.( 4.)	271.( 5.)	-12.	-12.( 4.)	-7.( 3.)
1409.96861	2	8	1	7	9	2	8	4.75E-02	2	-.6	523.	533.( 12.)	585.( 10.)	-111.	-111.( 7.)	-123.( 1.)
1411.32318	5	10	4	7	11	3	8	1.94E-03	1	-3.8	659.	688.( 12.)	780.( 8.)	106.	106.( 2.)	124.( 2.)
1411.50555	3	10	1	10	10	2	9	4.38E-02	2	1.8	368.	370.( 12.)	410.( 6.)	-23.	-23.( 1.)	-22.( 3.)
1411.95446	3	5	0	5	5	3	2	3.66E-02	2	.8	911.	905.( 15.)	1010.( 15.)	-45.	-45.( 4.)	-50.( 6.)
1412.07869	5	10	0	10	10	1	9	1.45E-02	2	-.7	387.	383.( 8.)	435.( 10.)	4.	4.( 6.)	10.( 3.)
1416.08625	2	8	2	7	9	1	8	1.42E-01	0	.7	460.	461.( 8.)	515.( 7.)	34.	34.( 3.)	51.( 3.)
1417.25327	2	8	0	8	9	1	9	1.30E-01	2	2.6	355.	363.( 5.)	399.( 12.)	-34.	-34.( 4.)	-29.( 4.)
1417.49846	1	8	1	8	9	0	9	3.85E-01	3	1.3	353.	347.( 7.)	390.( 8.)	-27.	-27.( 3.)	-22.( 2.)
1418.93299	2	4	2	2	5	3	3	4.66E-01	2	-.7	865.	861.( 7.)	975.( 12.)	14.	14.( 3.)	26.( 8.)
1419.31722	2	3	3	1	4	4	0	8.17E-01	1	-3.3	666.	659.( 15.)	749.( 10.)	-1.	-1.( 3.)	8.( 6.)
1419.50804	2	3	3	0	4	4	1	2.44E+00	1	-3.8	652.	655.( 8.)	745.( 6.)	17.	17.( 1.)	28.( 2.)
1423.70416	1	3	1	3	4	2	2	3.14E-01	2	.4	961.	951.( 10.)	1065.( 22.)	-28.	-28.( 2.)	-28.( 4.)
1424.12997	4	7	1	6	8	2	7	3.22E-01	3	1.7	651.	666.( 12.)	758.( 7.)	-91.	-91.( 3.)	-99.( 2.)
1425.84501	7	12	1	11	12	2	10	1.21E-03	1	1.9	310.	314.( 6.)	352.( 10.)	10.	10.( 4.)	17.( 4.)
1428.27108	3	8	3	6	9	2	7	4.47E-02	2	-3.3	686.	734.( 15.)	826.( 8.)	79.	79.( 4.)	94.( 2.)
1429.94505	1	3	2	2	4	3	1	8.00E-01	1	-1.4	837.	836.( 7.)	934.( 8.)	-31.	-31.( 2.)	-32.( 3.)
1431.99020	2	9	1	9	9	2	8	3.75E-02	2	2.2	446.	465.( 47.)	500.( 15.)	-26.	-25.( 12.)	-12.( 5.)
1433.20325	2	9	0	9	9	1	8	1.13E-01	1	1.8	472.	454.( 4.)	519.( 5.)	14.	14.( 2.)	23.( 2.)
1433.60864	5	4	0	4	4	3	1	1.60E-02	2	2.8	940.	929.( 11.)	1015.( 15.)	-65.	-65.( 3.)	-71.( 2.)
1435.64956	3	7	2	6	8	1	7	1.01E-01	2	-.4	574.	591.( 6.)	670.( 6.)	59.	58.( 5.)	75.( 3.)
1436.48022	3	7	0	7	8	1	8	7.92E-01	1	-.7	460.	462.( 3.)	522.( 5.)	-44.	-44.( 2.)	-47.( 5.)
1436.65551	2	6	1	5	7	2	6	2.12E-01	2	2.3	764.	757.( 28.)	850.( 22.)	-55.	-56.( 15.)	-60.( 14.)
1436.81822	2	3	2	1	4	3	2	2.52E+00	1	-1.8	844.	850.( 10.)	953.( 40.)	8.	8.( 2.)	15.( 3.)
1437.02621	3	7	1	7	8											

Table 2. continued

computed position	un	upper J K <sub>a</sub> K <sub>c</sub>	lower J K <sub>a</sub> K <sub>c</sub>	observed strength	t <sub>s</sub>	(o-c)%	air b°(sm)	air b°(obs.)	N <sub>2</sub> b°(obs.)	air d°(sm)	air d°(obs.)	N <sub>2</sub> d°(obs.)
1447.95163	2	5 1 4	6 2 5	1.10E+00	1	.5	848.	846.(-7.)	951.(-9.)	-48.	-48.(-2.)	-51.(-2.)
1452.06659	1	8 1 8	8 2 7	2.61E-01	1	1.6	533.	537.(-5.)	600.(-11.)	-26.	-26.(-3.)	-30.(-2.)
1454.57293	2	8 0 8	8 1 7	8.84E-02	1	1.5	569.	588.(-11.)	654.(-7.)	24.	24.(-2.)	33.(-3.)
1455.30131	2	6 0 6	7 1 7	5.05E-01	2	1.0	583.	594.(-8.)	670.(-7.)	-54.	-54.(-3.)	-55.(-4.)
1456.50975	3	6 1 6	7 0 7	1.49E+00	2	-4.	573.	595.(-12.)	665.(-9.)	-19.	-19.(-2.)	-15.(-4.)
1456.88707	4	2 2 1	3 3 0	4.11E+00	1	-1.9	820.	828.(-20.)	940.(-20.)	-19.	-19.(-3.)	-16.(-3.)
1457.07200	4	6 2 5	7 1 6	5.60E-01	1	-4.	696.	733.(-25.)	841.(-50.)	73.	62.(-16.)	81.(-32.)
1458.26699	1	2 2 0	3 3 1	1.40E+00	4	-7.	835.	841.(-18.)	927.(-15.)	4.	5.(-6.)	8.(-5.)
1458.30009	3	10 2 9	10 3 8	3.48E-02	3	-2.5	439.	410.(-20.)	0.(-0.)	-75.	0.(-0.)	0.(-0.)
1459.26093	2	4 1 3	5 2 4	5.88E-01	2	.1	897.	883.(-10.)	1000.(-12.)	-34.	-34.(-4.)	-32.(-9.)
1462.36521	5	13 2 11	13 3 10	5.55E-04	2	.8	409.	391.(-12.)	452.(-48.)	54.	54.(-4.)	62.(-30.)
1464.90506	2	2 1 2	3 2 1	2.18E+00	1	.6	953.	971.(-14.)	1060.(-8.)	-51.	-51.(-2.)	-55.(-2.)
1467.47250	7	12 3 10	12 4 9	2.05E-03	2	1.7	376.	372.(-7.)	425.(-6.)	-111.	-111.(-5.)	-129.(-2.)
1471.48165	3	7 1 7	7 2 6	1.77E-01	3	-2.4	628.	655.(-12.)	744.(-6.)	-32.	-32.(-4.)	-28.(-4.)
1472.05121	5	3 1 2	4 2 3	2.62E+00	1	-.2	919.	910.(-19.)	1025.(-14.)	-19.	-19.(-1.)	-17.(-3.)
1473.51416	3	5 0 5	6 1 6	2.52E+00	1	.5	714.	725.(-10.)	833.(-6.)	-60.	-60.(-1.)	-58.(-4.)
1474.36234	4	9 2 8	9 3 7	3.25E-02	3	-.9	520.	565.(-25.)	620.(-25.)	-82.	-82.(-10.)	-102.(-10.)
1476.13245	3	5 1 5	6 0 6	8.45E-01	2	2.0	698.	698.(-6.)	790.(-15.)	-14.	-14.(-2.)	-9.(-4.)
1476.42884	3	7 0 7	7 1 6	5.65E-01	1	0.	674.	704.(-7.)	787.(-6.)	23.	23.(-2.)	29.(-6.)
1480.24018	5	11 3 9	11 4 8	2.41E-03	2	.7	441.	443.(-44.)	499.(-50.)	-121.	-121.(-61.)	-140.(-70.)
1481.24687	1	5 2 4	6 1 5	2.82E-01	3	-1.3	816.	805.(-8.)	935.(-15.)	27.	27.(-4.)	38.(-3.)
1481.77832	2	8 4 5	9 3 6	1.02E-02	3	-2.2	772.	760.(-12.)	820.(-5.)	-21.	-21.(-4.)	4.(-9.)
1484.25726	5	10 5 6	11 4 7	4.20E-04	3	-4.8	653.	640.(-25.)	760.(-18.)	-49.	-50.(-15.)	-25.(-38.)
1486.15840	3	9 1 8	9 2 7	1.06E-01	4	-2.7	628.	653.(-15.)	744.(-20.)	37.	37.(-2.)	48.(-2.)
1487.34852	1	2 1 1	3 2 2	1.23E+00	1	1.6	935.	945.(-7.)	1058.(-7.)	-6.	-6.(-2.)	-7.(-2.)
1489.04989	2	8 2 7	8 3 6	2.44E-01	1	.2	605.	635.(-15.)	704.(-8.)	-87.	-87.(-6.)	-89.(-6.)
1489.30239	2	6 3 4	7 2 5	1.39E-01	2	-.1	852.	823.(-13.)	926.(-20.)	29.	29.(-3.)	34.(-5.)
1489.84191	3	6 1 6	6 2 5	1.04E+00	1	0.	724.	740.(-10.)	832.(-20.)	-35.	-35.(-4.)	-41.(-7.)
1490.82569	5	4 0 4	5 1 5	1.25E+00	1	1.8	841.	855.(-15.)	980.(-30.)	-60.	-63.(-4.)	-62.(-3.)
1491.39039	5	10 3 8	10 4 7	2.26E-02	2	-1.3	504.	522.(-9.)	574.(-36.)	-119.	-119.(-5.)	-141.(-5.)
1496.24890	2	4 1 4	5 0 5	3.58E+00	1	-.2	819.	812.(-14.)	906.(-12.)	-6.	-6.(-1.)	1.(-3.)
1498.80318	4	1 1 1	2 2 0	1.34E+00	1	.6	969.	966.(-9.)	1072.(-9.)	-59.	-59.(-2.)	-58.(-2.)
1498.87472	2	6 0 6	6 1 5	3.70E-01	3	-1.6	781.	820.(-20.)	944.(-53.)	22.	22.(-6.)	29.(-4.)
1500.54588	2	9 3 7	9 4 6	2.16E-02	2	.4	564.	586.(-24.)	657.(-43.)	-111.	-111.(-7.)	-137.(-24.)
1501.84565	3	7 2 6	7 3 5	1.78E-01	2	.1	688.	693.(-19.)	792.(-10.)	-76.	-76.(-5.)	-82.(-4.)
1505.60420	2	1 1 0	2 2 1	4.66E+00	1	-.9	971.	974.(-5.)	1083.(-25.)	-11.	-11.(-2.)	-6.(-4.)
1506.62031	3	5 1 5	5 2 4	5.79E-01	2	-1.9	814.	810.(-13.)	911.(-20.)	-38.	-38.(-3.)	-44.(-3.)
1507.05831	3	3 0 3	4 1 4	4.74E+00	1	.7	947.	915.(-10.)	1041.(-8.)	-60.	-60.(-1.)	-63.(-1.)
1507.44233	2	8 1 7	8 2 6	9.63E-02	3	-1.6	741.	733.(-10.)	825.(-25.)	16.	16.(-6.)	15.(-4.)
1507.48404	3	8 3 6	8 4 5	1.55E-01	3	-2.3	618.	631.(-22.)	705.(-15.)	-82.	-82.(-11.)	-84.(-8.)
1507.77929	2	6 5 2	6 6 1	6.10E-02	3	-2.6	502.	502.(-10.)	565.(-15.)	32.	32.(-4.)	28.(-6.)
1507.82135	2	6 5 1	6 6 0	2.07E-02	2	-.8	515.	522.(-19.)	550.(-40.)	35.	35.(-6.)	32.(-5.)
1507.85166	3	7 5 3	7 6 2	1.73E-02	2	-1.4	500.	492.(-12.)	555.(-30.)	31.	31.(-13.)	32.(-7.)
1507.97259	3	7 5 2	7 6 1	5.27E-02	4	.1	507.	507.(-6.)	580.(-15.)	30.	30.(-4.)	28.(-4.)
1508.02149	2	8 5 4	8 6 3	2.88E-02	2	-4.0	486.	486.(-6.)	552.(-15.)	26.	26.(-6.)	12.(-15.)
1508.55879	2	4 2 3	5 1 4	1.03E+00	1	.3	914.	880.(-8.)	1003.(-10.)	38.	38.(-9.)	36.(-6.)
1509.53067	2	8 4 5	8 5 4	7.77E-02	3	-.5	587.	565.(-20.)	640.(-25.)	-31.	-36.(-5.)	-25.(-12.)
1509.62227	3	5 4 2	5 5 1	8.50E-02	5	-.5	658.	637.(-35.)	700.(-50.)	45.	45.(-6.)	67.(-2.)
1509.86130	2	7 4 4	7 5 3	4.96E-02	2	-2.7	609.	560.(-25.)	630.(-15.)	8.	8.(-3.)	19.(-16.)
1510.53281	2	6 4 2	6 5 1	8.00E-02	4	.2	672.	619.(-24.)	710.(-14.)	21.	21.(-2.)	41.(-11.)
1512.21053	3	7 3 5	7 4 4	1.10E-01	3	-1.2	664.	635.(-32.)	720.(-40.)	-76.	-76.(-7.)	-87.(-44.)
1514.98743	2	6 3 4	6 4 3	5.88E-01	0	.1	700.	668.(-10.)	759.(-8.)	-59.	-59.(-2.)	-66.(-4.)
1515.77859	5	8 4 4	8 5 3	2.57E-02	2	-2.4	721.	696.(-15.)	745.(-18.)	49.	49.(-11.)	61.(-6.)
1516.29326	3	5 3 3	5 4 2	2.71E-01	1	-1.3	727.	688.(-7.)	768.(-4.)	-25.	-25.(-4.)	-24.(-3.)
1516.70798	3	4 3 2	4 4 1	7.57E-01	2	-3.6	744.	735.(-19.)	818.(-7.)	4.	4.(-4.)	15.(-5.)
1517.43094	1	3 1 3	4 0 4	1.47E+00	1	1.9	919.	895.(-40.)	997.(-5.)	14.	14.(-5.)	21.(-2.)
1517.78284	1	4 3 1	4 4 0	2.61E-01	3	-.5	768.	763.(-20.)	846.(-6.)	12.	12.(-1.)	22.(-2.)
1519.35028	2	7 4 4	8 3 5	6.28E-03	2	-1.2	804.	797.(-16.)	898.(-60.)	-28.	-28.(-2.)	-28.(-14.)
1520.15312	2	5 3 2	5 4 1	8.60E-01	5	3.2	779.	790.(-30.)	920.(-35.)	14.	14.(-12.)	35.(-20.)
1520.18455	1	5 2 4	5 3 3	5.50E-01	5	1.5	817.	824.(-40.)	0.(-0.)	-65.	-65.(-14.)	0.(-0.)
1521.23452	2	4 1 4	4 2 3	2.64E+00	2	1.0	891.	878.(-25.)	970.(-12.)	-22.	-22.(-4.)	-28.(-19.)
1521.30900	3	5 0 5	5 1 4	2.04E+00	2	-3.1	881.	880.(-30.)	1000.(-40.)	-8.	-3.(-12.)	-11.(-22.)
1521.46895	4	9 4 5	9 5 4	3.40E-02	2	-.9	730.	703.(-15.)	0.(-0.)	53.	53.(-18.)	0.(-0.)
1522.68607	2	2 0 2	3 1 3	1.80E+00	1	3.0	1016.	983.(-8.)	1095.(-11.)	-54.	-54.(-4.)	-55.(-3.)
1523.63419	3	5 3 3	6 2 4	6.02E-02	1	.8	889.	870.(-20.)	953.(-10.)	10.	10.(-11.)	8.(-3.)
1524.80938	3	6 3 3	6 4 2	2.01E-01	2	-.6	796.	797.(-14.)	913.(-17.)	12.	12.(-4.)	31.(-7.)
1525.49942	2	4 2 3	4 3 2	2.06E+00	2	-1.0	847.	827.(-8.)	933.(-7.)	-55.	-55.(-2.)	-57.(-1.)
1527.32036	4	7 1 6	7 2 5	7.26E-01	1	-1.3	833.	815.(-13.)	927.(-6.)	-19.	-19.(-2.)	-22.(-2.)
1528.56822	1	3 2 2	3 3 1	6.01E-01	1	-.6	843.	848.(-11.)	947.(-8.)	-21.	-21.(-2.)	-17.(-2.)
1531.63816	2	7 3 4	7 4 3	3.63E-01	1	1.1	812.	800.(-12.)	911.(-15.)	12.	12.(-3.)	19.(-3.)
1533.18227	1	3 1 3	3 2 2	1.07E+00	1	1.0	945.	934.(-15.)	1050.(-40.)	-45.	-45.(-4.)	-42.(-3.)
1533.91653	2	3 2 1	3 3 0	1.85E+00	2	-1.1	868.	865.(-12.)	980.(-25.)	-17.	-17.(-2.)	-15.(-1.)
1535.47896	3	9 2 7	9 3 6	1.05E-01	3	-.1	788.	800.(-15.)	908.(-19.)	-73.	-73.(-8.)	-86.(-5.)
1538.29053	1	3 2 2	4 1 3	3.10E-01	5	1.1	968.	955.(-35.)	1065.(-40.)	48.	48.(-7.)	64.(-7.)
1540.29977	2	2 1 2	3 0 3	4.06E+00	1	.8	981.	971.(-15.)	1082.(-15.)	3.	3.(-3.)	6.(-4.)

Table 2. continued

computed position	un	upper J	K <sub>a</sub>	K <sub>c</sub>	lower J	K <sub>a</sub>	K <sub>c</sub>	observed strength	t <sub>s</sub>	(o-c)%	air b°(sm)	air b°(obs.)	N <sub>2</sub> b°(obs.)	air d°(sm)	air d°(obs.)	N <sub>2</sub> d°(obs.)
1541.95412	5	4	0	4	4	1	3	1.23E+00	2	.3	964.	940.( 25.)	1065.( 35.)	-11.	-11.( 3.)	-12.( 3.)
1542.15978	2	2	1	2	2	2	1	2.71E+00	1	-.6	967.	972.( 15.)	1091.( 30.)	-29.	-29.( 7.)	-27.( 4.)
1543.49023	2	6	1	5	6	2	4	5.42E-01	3	-2.3	897.	883.( 11.)	997.( 15.)	-31.	-31.( 3.)	-33.( 3.)
1544.43506	3	9	3	6	9	4	5	7.32E-02	3	-2.7	815.	820.( 23.)	927.( 20.)	-99.	-99.( 11.)	-103.( 22.)
1545.15661	3	5	2	3	5	3	2	1.95E+00	1	-.6	884.	868.( 13.)	961.( 10.)	-13.	-13.( 2.)	-11.( 1.)
1545.65524	4	8	2	6	8	3	5	9.79E-02	2	-1.4	860.	885.( 18.)	1012.( 30.)	-67.	-67.( 3.)	-75.( 7.)
1549.64169	2	6	2	4	6	3	3	4.37E-01	1	-.7	902.	866.( 7.)	984.( 8.)	-61.	-61.( 3.)	-70.( 3.)
1550.23594	2	7	2	5	7	3	4	6.90E-01	1	-1.6	897.	883.( 9.)	995.( 15.)	-74.	-74.( 3.)	-82.( 3.)
1553.00540	4	7	1	6	6	4	3	3.00E-03	1	-1.5	810.	808.( 17.)	865.( 40.)	-76.	-75.( 6.)	-83.( 42.)
1554.35234	2	5	1	4	5	2	3	3.17E+00	1	-.7	930.	924.( 14.)	1033.( 20.)	-58.	-58.( 2.)	-68.( 2.)
1556.02488	3	6	4	3	7	3	4	2.95E-02	2	-.8	823.	892.( 28.)	975.( 25.)	-16.	-16.( 2.)	-14.( 3.)
1557.48603	1	2	1	1	2	2	0	1.32E+00	3	3.5	981.	965.( 20.)	1085.( 15.)	-15.	-15.( 5.)	-15.( 20.)
1557.60918	5	0	0	0	1	1	1	4.14E+00	4	-1.2	991.	1005.( 25.)	1112.( 60.)	-31.	-28.( 4.)	-21.( 15.)
1558.30500	3	4	3	2	5	2	3	1.84E-01	4	1.4	898.	900.( 30.)	978.( 60.)	19.	19.( 9.)	27.( 10.)
1558.53089	3	3	0	3	3	1	2	5.69E+00	2	-1.3	1018.	980.( 40.)	1069.( 60.)	-31.	-31.( 8.)	-12.( 6.)
1559.69013	2	4	1	3	4	2	2	1.61E+00	1	-.1	943.	953.( 13.)	1085.( 35.)	-58.	-58.( 3.)	-57.( 5.)
1560.25713	5	3	1	2	3	2	1	5.31E+00	2	-1.2	952.	970.( 25.)	1065.( 25.)	-56.	-56.( 6.)	-55.( 6.)
1564.87629	4	1	1	1	2	0	2	8.23E-01	2	3.3	989.	1007.( 8.)	1116.( 9.)	8.	8.( 3.)	18.( 3.)
1566.02322	2	7	4	3	8	3	6	1.25E-02	2	-1.4	692.	709.( 16.)	785.( 30.)	57.	57.( 4.)	77.( 13.)
1568.93984	4	2	2	1	3	1	2	5.27E-01	2	1.4	958.	975.( 30.)	1061.( 10.)	26.	26.( 6.)	26.( 6.)
1569.78862	2	2	0	2	2	1	1	2.48E+00	1	2.2	1033.	1015.( 25.)	1128.( 14.)	-53.	-53.( 5.)	-53.( 2.)
1572.98135	3	6	3	3	7	2	6	1.11E-02	1	2.0	849.	822.( 9.)	930.( 50.)	35.	35.( 5.)	35.( 17.)
1576.18542	6	1	0	1	1	1	0	6.45E+00	1	.7	1001.	1032.( 20.)	1169.( 10.)	-67.	-67.( 6.)	-71.( 3.)
1577.58290	2	5	3	2	6	2	5	7.74E-02	5	.0	864.	845.( 15.)	945.( 14.)	47.	47.( 5.)	56.( 7.)
1578.31637	3	7	1	7	6	2	4	4.66E-03	1	-.4	867.	892.( 19.)	968.( 16.)	-18.	-21.( 7.)	-20.( 2.)
1579.24713	4	8	5	3	9	4	6	7.88E-04	2	1.5	601.	608.( 22.)	705.( 15.)	-57.	-57.( 13.)	-60.( 6.)
1582.47122	2	6	4	2	7	3	5	8.40E-03	2	.8	730.	719.( 11.)	803.( 25.)	13.	13.( 2.)	20.( 2.)
1589.70827	1	4	3	1	5	2	4	4.07E-02	2	1.7	874.	850.( 40.)	950.( 16.)	47.	47.( 6.)	50.( 3.)
1590.14638	3	5	4	2	6	3	3	1.24E-02	2	-.8	833.	826.( 9.)	910.( 15.)	6.	6.( 1.)	11.( 2.)
1591.67185	2	3	3	1	4	2	2	4.08E-02	2	2.4	888.	905.( 20.)	995.( 25.)	26.	26.( 5.)	29.( 2.)
1592.26586	3	7	5	3	8	4	4	1.56E-03	2	-.7	714.	747.( 8.)	808.( 50.)	-53.	-53.( 6.)	-72.( 36.)
1594.49672	2	3	2	1	4	1	4	1.70E-01	3	2.9	961.	945.( 16.)	1032.( 6.)	34.	34.( 5.)	37.( 2.)
1596.24262	3	6	1	6	5	2	3	4.48E-02	2	-.5	915.	925.( 15.)	1040.( 20.)	-24.	0.( 0.)	0.( 0.)
1601.45856	3	7	5	2	8	4	5	4.60E-03	2	.1	610.	632.( 12.)	728.( 8.)	-45.	-45.( 6.)	-58.( 3.)
1602.29454	9	9	6	3	10	5	6	2.83E-04	2	1.1	535.	536.( 11.)	587.( 1.)	-101.	-101.( 7.)	-114.( 21.)
1602.88379	2	5	4	1	6	3	4	3.45E-02	2	-.9	767.	783.( 30.)	838.( 15.)	-20.	-20.( 10.)	8.( 6.)
1603.31978	1	3	1	3	2	2	0	1.07E-01	4	1.6	994.	1005.( 36.)	1085.( 25.)	-27.	-27.( 3.)	-27.( 2.)
1606.71631	3	5	2	3	6	1	6	2.52E-02	2	3.4	915.	948.( 21.)	1014.( 30.)	5.	5.( 3.)	2.( 10.)
1607.04951	3	5	1	5	4	2	2	4.33E-02	3	1.1	942.	967.( 13.)	1055.( 25.)	5.	5.( 4.)	7.( 4.)
1607.25345	2	3	3	0	4	2	3	1.03E-01	1	1.4	877.	890.( 40.)	960.( 15.)	36.	36.( 4.)	40.( 5.)
1609.44044	2	4	1	4	3	2	1	2.70E-01	2	-1.6	961.	961.( 11.)	1047.( 6.)	-22.	-22.( 5.)	-19.( 2.)
1611.03635	3	9	3	6	10	2	9	4.80E-04	2	3.2	808.	778.( 18.)	870.( 40.)	56.	56.( 9.)	92.( 12.)
1616.71149	2	1	1	0	1	0	1	5.83E+00	1	1.4	1020.	1025.( 20.)	1155.( 25.)	55.	55.( 2.)	62.( 2.)
1620.78713	2	4	4	1	5	3	2	2.88E-02	2	-.3	836.	831.( 20.)	929.( 48.)	12.	12.( 5.)	15.( 1.)
1621.62013	2	6	5	2	7	4	3	6.70E-03	2	-.3	697.	755.( 8.)	848.( 40.)	-42.	-40.( 20.)	-35.( 27.)
1622.59773	2	4	2	3	3	3	0	2.06E-01	3	-.6	877.	867.( 25.)	965.( 20.)	-39.	-39.( 2.)	-38.( 4.)
1623.55914	1	2	1	1	2	0	2	2.08E+00	1	1.2	1027.	1038.( 11.)	1152.( 30.)	54.	54.( 12.)	54.( 4.)
1625.13579	2	6	5	1	7	4	4	2.24E-03	1	.5	631.	644.( 20.)	726.( 13.)	-35.	-35.( 3.)	-30.( 3.)
1625.65052	3	4	4	0	5	3	3	9.55E-03	2	1.2	769.	790.( 8.)	887.( 6.)	-4.	-4.( 4.)	-7.( 4.)
1627.82743	2	2	0	2	1	1	1	1.05E+00	1	2.1	979.	1000.( 15.)	1124.( 35.)	-14.	-14.( 3.)	-20.( 4.)
1634.96709	4	1	1	1	0	0	0	1.50E+00	1	2.6	981.	1020.( 30.)	1125.( 20.)	33.	33.( 5.)	38.( 5.)
1635.65184	5	3	1	2	3	0	3	4.44E+00	2	-.1	1008.	990.( 30.)	1065.( 15.)	44.	44.( 5.)	45.( 2.)
1637.51185	5	3	1	2	2	2	1	8.15E-01	1	-.4	923.	948.( 8.)	1053.( 14.)	-15.	-13.( 2.)	-14.( 5.)
1637.68174	2	4	2	2	3	3	1	7.97E-02	1	-.9	888.	924.( 25.)	1003.( 25.)	-10.	-10.( 4.)	-11.( 10.)
1638.27352	3	5	3	3	4	4	0	2.43E-02	1	-.4	769.	758.( 17.)	832.( 49.)	-18.	-18.( 3.)	-4.( 4.)
1640.31013	1	5	2	4	4	3	1	8.43E-02	1	-.8	874.	880.( 25.)	980.( 30.)	-40.	-40.( 2.)	-39.( 5.)
1640.43593	4	9	2	8	8	3	5	1.78E-03	2	-4.3	817.	820.( 50.)	1021.( 50.)	-13.	-13.( 7.)	-8.( 4.)
1642.38659	2	5	3	2	4	4	1	7.33E-02	2	-1.6	836.	822.( 24.)	885.( 15.)	-5.	-5.( 2.)	4.( 6.)
1645.96930	2	3	2	1	3	1	2	4.00E+00	2	.5	952.	975.( 35.)	1072.( 15.)	15.	26.( 9.)	22.( 3.)
1647.40405	2	4	2	2	4	1	3	1.17E+00	1	.3	943.	936.( 10.)	1060.( 44.)	53.	55.( 3.)	67.( 6.)
1648.31040	1	2	2	0	2	1	1	9.82E-01	2	2.8	981.	975.( 25.)	1090.( 40.)	22.	22.( 4.)	23.( 9.)
1649.41827	3	5	5	0	6	4	3	5.75E-03	2	-1.3	677.	685.( 11.)	809.( 40.)	-34.	-34.( 2.)	-49.( 25.)
1652.40031	3	3	0	3	2	1	2	5.67E+00	1	-1.1	969.	948.( 20.)	1072.( 25.)	-20.	-22.( 10.)	-12.( 11.)
1653.26707	2	2	1	2	1	0	1	5.95E+00	2	-.7	1034.	995.( 25.)	1175.( 45.)	44.	44.( 7.)	60.( 8.)
1653.41691	2	4	1	3	4	0	4	8.03E-01	2	-4.7	958.	936.( 15.)	1075.( 20.)	32.	32.( 6.)	68.( 5.)
1654.51115	3	5	2	3	5	1	4	2.16E+00	1	-1.0	930.	940.( 20.)	1065.( 25.)	54.	54.( 3.)	65.( 4.)
1656.30518	3	6	4	3	5	5	0	1.85E-02	2	-2.8	677.	672.( 8.)	749.( 11.)	12.	12.( 1.)	35.( 19.)
1656.99098	3	7	2	6	6	3	3	2.40E-02	2	.1	849.	852.( 19.)	951.( 10.)	-9.	-9.( 5.)	-12.( 7.)
1657.09244	2	6	4	2	5	5	1	6.25E-03	2	-1.7	668.	672.( 15.)	770.( 50.)	26.	26.( 5.)	46.( 23.)
1661.37105	2	6	3	4	5	4	1	9.00E-02	3	-4.4	767.	731.( 10.)	812.( 20.)	-46.	-46.( 4.)	-46.( 2.)
1662.80926	4	2	2	1	2	1	2	2.00E+00	1	1.6	967.	977.( 6.)	1068.( 10.)	34.	34.( 3.)	

Table 2. continued

computed position	un	upper		lower		observed strength	ts	air		N <sub>2</sub>		air		N <sub>2</sub>		
		J	K <sub>a</sub>	K <sub>c</sub>	J	K <sub>a</sub>	K <sub>c</sub>	(o-c)t	b°(sm)	b°(obs.)	b°(obs.)	d°(sm)	d°(obs.)	d°(obs.)		
1671.50908	1	3	2	2	3	1	3	7.38E-01	1	2.1	945.	947.( 10.)	1045.( 16.)	36.	45.( 14.)	55.( 14.)
1672.47514	3	6	3	3	5	4	2	3.26E-02	1	-1.9	833.	832.( 20.)	932.( 20.)	14.	14.( 7.)	22.( 3.)
1675.17267	5	4	0	4	3	1	3	2.33E+00	1	.8	906.	893.( 10.)	996.( 8.)	-18.	-18.( 1.)	-21.( 2.)
1675.51511	2	5	1	4	5	0	5	1.30E+00	1	1.6	880.	875.( 15.)	984.( 8.)	1.	3.( 1.)	9.( 2.)
1678.98309	3	7	5	3	6	6	0	1.26E-03	1	-1.2	580.	561.( 12.)	630.( 15.)	31.	31.( 8.)	23.( 30.)
1679.10915	3	7	5	2	6	6	1	3.77E-03	2	-1.5	580.	585.( 12.)	666.( 15.)	29.	29.( 4.)	51.( 15.)
1679.46777	3	4	3	2	5	0	5	5.90E-03	3	1.0	890.	892.( 34.)	980.( 50.)	48.	47.( 4.)	58.( 29.)
1679.81607	3	6	3	3	6	2	4	2.52E-01	3	-3.6	902.	865.( 15.)	983.( 20.)	14.	14.( 4.)	10.( 4.)
1680.46544	2	7	3	4	7	2	5	4.07E-01	1	-.4	897.	873.( 15.)	982.( 20.)	54.	54.( 5.)	65.( 5.)
1682.17424	3	7	3	5	6	4	2	2.28E-02	1	-2.3	730.	743.( 3.)	825.( 10.)	-56.	-56.( 5.)	-62.( 20.)
1683.17792	2	4	2	3	4	1	4	1.68E+00	1	1.2	891.	885.( 8.)	978.( 10.)	41.	41.( 4.)	53.( 3.)
1683.98361	2	5	3	2	5	2	3	1.17E+00	1	.1	884.	885.( 8.)	998.( 7.)	-7.	-7.( 2.)	-10.( 2.)
1684.83515	2	4	1	4	3	0	3	7.40E+00	1	-.1	954.	940.( 50.)	1045.( 20.)	52.	52.( 3.)	64.( 7.)
1687.87789	5	8	3	5	8	2	6	5.50E-02	3	.4	860.	910.( 35.)	1036.( 15.)	81.	81.( 2.)	98.( 5.)
1688.37848	2	7	2	5	7	1	6	4.02E-01	1	-1.0	833.	812.( 15.)	910.( 7.)	46.	46.( 3.)	64.( 3.)
1690.13747	1	4	3	1	4	2	2	4.64E-01	1	1.3	865.	895.( 8.)	1005.( 8.)	12.	12.( 6.)	14.( 3.)
1695.45937	2	3	3	0	3	2	1	1.16E+00	1	1.2	868.	878.( 7.)	980.( 7.)	24.	24.( 2.)	25.( 4.)
1695.92813	3	5	0	5	4	1	4	6.41E+00	1	-1.8	807.	795.( 20.)	900.( 40.)	3.	3.( 1.)	5.( 1.)
1697.52718	1	5	2	4	5	1	5	3.45E-01	3	.1	814.	808.( 7.)	912.( 10.)	42.	42.( 2.)	54.( 3.)
1698.95547	3	8	3	6	7	4	3	3.55E-02	2	-2.0	692.	705.( 20.)	810.( 45.)	-47.	-47.( 5.)	-66.( 6.)
1699.56713	2	6	1	5	6	0	6	2.02E-01	2	-1.0	780.	800.( 25.)	888.( 20.)	-30.	-30.( 6.)	-26.( 5.)
1699.93390	4	2	2	1	1	1	0	4.44E+00	2	.8	949.	990.( 15.)	1102.( 8.)	9.	9.( 3.)	10.( 2.)
1700.50073	2	5	1	4	4	2	3	1.75E+00	1	-1.0	921.	895.( 20.)	995.( 8.)	-54.	-54.( 6.)	-59.( 2.)
1700.77629	3	5	1	5	4	0	4	2.21E+00	1	-.5	847.	865.( 20.)	968.( 15.)	47.	47.( 3.)	55.( 2.)
1701.14996	2	3	3	1	3	2	2	3.67E-01	1	-.8	843.	860.( 15.)	975.( 15.)	28.	28.( 3.)	30.( 4.)
1702.74890	3	9	3	6	9	2	7	5.35E-02	2	1.7	788.	835.( 15.)	940.( 28.)	113.	113.( 6.)	132.( 2.)
1703.43842	2	8	5	4	7	6	1	4.12E-03	3	-1.8	554.	543.( 7.)	599.( 50.)	-5.	-5.( 1.)	0.( 0.)
1704.45339	3	4	3	2	4	2	3	1.23E+00	1	-.1	847.	836.( 7.)	937.( 7.)	30.	30.( 2.)	37.( 3.)
1706.15048	2	7	3	4	6	4	3	7.96E-02	1	-3.4	823.	830.( 25.)	948.( 15.)	24.	24.( 16.)	47.( 20.)
1706.34921	1	2	2	0	1	1	1	1.27E+00	1	2.7	966.	980.( 10.)	1075.( 30.)	49.	49.( 2.)	47.( 1.)
1707.22250	2	6	2	4	5	3	3	1.23E-01	1	-2.4	889.	870.( 20.)	948.( 20.)	5.	5.( 4.)	9.( 5.)
1708.78951	3	5	4	2	6	1	5	4.52E-04	1	.6	760.	789.( 31.)	827.( 30.)	52.	49.( 10.)	35.( 17.)
1710.19895	3	5	3	3	5	2	4	3.06E-01	1	-.3	817.	804.( 11.)	887.( 8.)	45.	45.( 4.)	59.( 4.)
1712.04348	5	8	4	4	7	5	3	5.59E-03	1	-.4	714.	693.( 8.)	779.( 5.)	43.	43.( 5.)	56.( 2.)
1712.49102	5	10	3	8	9	4	5	3.70E-03	2	-1.1	774.	835.( 17.)	906.( 11.)	-54.	-54.( 6.)	-63.( 0.)
1712.92258	4	8	2	6	8	1	7	4.76E-02	1	-.4	741.	710.( 29.)	804.( 17.)	7.	7.( 4.)	16.( 6.)
1714.03369	4	6	2	5	6	1	6	5.51E-01	1	-.7	724.	711.( 6.)	788.( 7.)	29.	29.( 3.)	43.( 2.)
1715.15503	2	6	0	6	5	1	5	1.71E+00	0	-.3	689.	708.( 15.)	799.( 7.)	11.	11.( 2.)	13.( 2.)
1715.84721	4	9	4	5	9	3	6	3.60E-02	2	-.2	832.	795.( 15.)	920.( 20.)	46.	46.( 9.)	52.( 6.)
1717.40539	3	6	1	6	5	0	5	5.11E+00	1	-1.4	720.	727.( 20.)	820.( 25.)	37.	37.( 0.)	46.( 2.)
1718.61163	1	3	2	2	2	1	1	1.31E+00	1	1.5	980.	955.( 20.)	1053.( 10.)	12.	12.( 3.)	16.( 3.)
1718.80083	2	6	3	4	6	2	5	5.35E-01	1	-1.4	761.	737.( 17.)	837.( 7.)	57.	57.( 3.)	74.( 2.)
1721.53246	5	8	4	4	8	3	5	2.88E-02	2	.9	845.	839.( 28.)	966.( 33.)	-18.	-18.( 5.)	-27.( 3.)
1722.64711	4	11	4	7	11	3	8	3.47E-03	1	1.9	763.	795.( 13.)	911.( 7.)	128.	128.( 5.)	147.( 1.)
1723.48664	4	7	1	6	7	0	7	2.70E-01	2	-2.4	668.	691.( 10.)	774.( 8.)	-50.	-50.( 3.)	-53.( 3.)
1724.29029	5	10	3	7	10	2	8	4.97E-03	2	4.5	692.	695.( 20.)	784.( 35.)	105.	105.( 3.)	132.( 5.)
1727.41149	4	9	4	6	8	5	3	2.84E-03	2	-.6	601.	593.( 8.)	665.( 12.)	-48.	-48.( 3.)	-58.( 2.)
1727.83390	3	9	5	5	8	6	2	9.05E-04	2	-1.1	540.	507.( 6.)	562.( 20.)	-10.	-10.( 3.)	-16.( 6.)
1729.78257	2	7	4	3	7	3	4	1.71E-01	3	-.2	846.	855.( 10.)	970.( 7.)	-15.	-15.( 2.)	-19.( 5.)
1730.05499	2	6	1	5	5	2	4	5.31E-01	1	-.2	823.	827.( 8.)	933.( 10.)	-64.	-64.( 3.)	-73.( 3.)
1730.34621	3	7	3	5	7	2	6	8.62E-02	2	-2.9	688.	700.( 20.)	754.( 9.)	66.	66.( 4.)	97.( 7.)
1732.06070	3	7	2	6	7	1	7	8.66E-02	2	-1.8	628.	625.( 15.)	695.( 15.)	9.	9.( 4.)	24.( 4.)
1733.39053	3	7	0	7	6	1	6	3.48E+00	1	-1.4	569.	560.( 20.)	620.( 20.)	10.	10.( 1.)	17.( 2.)
1734.39327	3	7	1	7	6	0	6	1.16E+00	1	-1.6	590.	615.( 15.)	685.( 6.)	36.	36.( 2.)	46.( 3.)
1734.65050	2	4	2	3	3	1	2	3.25E+00	1	.1	977.	932.( 15.)	1033.( 13.)	20.	20.( 2.)	25.( 3.)
1737.61655	2	6	4	2	6	3	3	9.77E-02	1	-.3	836.	848.( 17.)	958.( 11.)	-2.	-2.( 1.)	11.( 6.)
1739.31849	3	9	2	7	9	1	8	4.75E-02	2	.0	628.	642.( 7.)	697.( 18.)	-71.	-71.( 6.)	-67.( 9.)
1739.83872	2	3	2	1	2	1	2	2.27E+00	1	2.0	977.	969.( 19.)	1085.( 20.)	49.	49.( 3.)	54.( 5.)
1743.05043	2	5	4	1	5	3	2	4.03E-01	1	-2.6	816.	824.( 20.)	910.( 35.)	7.	7.( 2.)	6.( 4.)
1743.61383	2	7	2	5	6	3	4	2.98E-01	2	-.1	852.	803.( 10.)	905.( 15.)	-29.	-29.( 5.)	-30.( 7.)
1744.59236	3	8	3	6	8	2	7	1.09E-01	2	-2.9	605.	605.( 8.)	670.( 20.)	84.	84.( 3.)	103.( 5.)
1745.77610	3	4	4	0	4	3	1	1.32E-01	1	-1.2	789.	780.( 10.)	883.( 8.)	-6.	-6.( 3.)	-8.( 7.)
1746.29039	2	8	1	7	8	0	8	3.83E-02	2	-1.0	556.	563.( 15.)	630.( 10.)	-63.	-63.( 8.)	-65.( 4.)
1747.08230	2	4	4	1	4	3	2	3.90E-01	3	-2.5	744.	774.( 20.)	868.( 7.)	-12.	-12.( 3.)	-15.( 4.)
1747.72719	3	5	4	2	5	3	3	1.34E-01	2	-1.7	727.	750.( 8.)	838.( 7.)	-5.	-5.( 2.)	-5.( 6.)
1748.65561	1	5	2	4	4	1	3	8.62E-01	1	.9	936.	895.( 30.)	1005.( 11.)	29.	29.( 2.)	33.( 3.)
1749.40277	3	6	4	3	6	3	4	2.75E-01	4	-2.8	700.	720.( 15.)	808.( 15.)	-5.	-5.( 2.)	1.( 7.)
1750.98407	2	8	0	8	7	1	7	6.93E-01	7	-2.9	457.	463.( 20.)	555.( 35.)	7.	3.( 29.)	20.( 3.)
1751.00316	2	8	2	7	8	1	8	1.11E-01	1	-2.4	533.	533.( 15.)	0.( 0.)	30.	30.( 40.)	32.( 15.)
1751.42326	1	8	1	8	7	0	7	2.09E+00	2	-2.5	471.	475.( 10.)	540.( 25.)	21.	21	

Table 2. continued

computed position	un	upper J	K <sub>a</sub>	K <sub>c</sub>	lower J	K <sub>a</sub>	K <sub>c</sub>	observed strength	t <sub>s</sub>	(o-c)t	air b°(sm)	N <sub>2</sub> b°(obs.)	air d°(sm)	N <sub>2</sub> d°(obs.)	air d°(obs.)	N <sub>2</sub> d°(obs.)
1761.82853	4	6	2	5	5	1	4	1.87E+00	1	-3.	860.	870.( 20.)	968.( 7.)	25.	25.( 2.)	32.( 4.)
1765.38026	6	10	2	8	10	1	9	5.03E-03	2	1.9	511.	530.( 9.)	604.( 13.)	-102.	-102.( 5.)	-112.( 6.)
1767.09177	4	9	4	6	9	3	7	9.28E-03	2	3.6	564.	568.( 8.)	626.( 5.)	72.	72.( 3.)	97.( 2.)
1767.91155	3	9	1	8	9	0	9	4.40E-02	3	-2.1	452.	446.( 7.)	500.( 11.)	-64.	-64.( 4.)	-70.( 5.)
1768.12016	2	9	0	9	8	1	8	1.16E+00	2	.0	360.	370.( 12.)	407.( 4.)	1.	1.( 1.)	6.( 1.)
1768.31198	2	9	1	9	8	0	8	3.79E-01	2	-2.0	367.	365.( 10.)	407.( 4.)	8.	8.( 3.)	15.( 3.)
1770.38361	4	9	2	8	9	1	9	1.46E-02	1	-1.5	446.	440.( 13.)	480.( 12.)	-14.	-14.( 8.)	-10.( 5.)
1771.28747	2	3	3	1	2	2	0	1.19E+00	1	.0	856.	845.( 15.)	941.( 9.)	21.	21.( 3.)	17.( 2.)
1772.71409	2	3	3	0	2	2	1	3.53E+00	1	-.2	830.	837.( 8.)	926.( 15.)	26.	26.( 2.)	26.( 1.)
1775.63411	3	7	2	6	6	1	5	4.15E-01	1	.3	757.	790.( 15.)	894.( 7.)	28.	28.( 2.)	36.( 3.)
1778.41833	5	10	4	7	10	3	8	9.23E-03	4	4.0	504.	500.( 16.)	546.( 12.)	105.	105.( 2.)	129.( 10.)
1779.11867	4	8	2	6	7	3	5	6.48E-02	2	-.8	783.	760.( 30.)	892.( 15.)	-70.	-70.( 30.)	-64.( 32.)
1780.62260	2	4	2	2	3	1	3	3.61E-01	1	3.7	973.	961.( 9.)	1044.( 10.)	45.	45.( 6.)	52.( 4.)
1780.74583	2	8	1	7	7	2	6	2.35E-01	1	-.2	571.	588.( 12.)	663.( 11.)	-85.	-85.( 5.)	-95.( 6.)
1781.96186	3	9	3	6	8	4	5	2.80E-02	2	-1.9	772.	762.( 12.)	850.( 50.)	15.	15.( 2.)	29.( 28.)
1784.88687	4	10	0	10	9	1	9	1.91E-01	2	1.3	280.	285.( 15.)	310.( 7.)	-12.	-12.( 2.)	-9.( 3.)
1784.97125	3	10	1	10	9	0	9	5.69E-01	2	.5	283.	279.( 13.)	300.( 10.)	-.8.	-.8.( 2.)	-2.( 2.)
1788.35644	4	8	5	3	8	4	4	1.04E-02	2	-.7	721.	769.( 9.)	877.( 10.)	-51.	-51.( 3.)	-54.( 2.)
1788.61387	4	10	1	9	10	0	10	5.18E-03	2	-2.8	362.	355.( 8.)	388.( 7.)	-51.	-51.( 5.)	-53.( 2.)
1789.87846	3	10	2	9	10	1	10	1.53E-02	2	-3.9	368.	359.( 19.)	403.( 12.)	-17.	-17.( 2.)	-12.( 1.)
1790.00770	3	11	2	9	11	1	10	4.20E-03	3	-2.3	402.	404.( 7.)	448.( 4.)	-110.	-110.( 2.)	-119.( 3.)
1790.95178	2	8	2	7	7	1	6	7.22E-01	2	-.5	640.	695.( 17.)	774.( 6.)	41.	41.( 3.)	49.( 3.)
1792.65931	3	4	3	2	3	2	1	2.41E+00	1	-.2	859.	895.( 15.)	994.( 15.)	4.	4.( 2.)	-3.( 1.)
1792.92999	3	7	5	2	7	4	3	6.15E-02	2	-1.9	699.	730.( 15.)	827.( 17.)	-27.	-27.( 13.)	-31.( 16.)
1795.09950	2	6	5	1	6	4	2	3.29E-02	2	-1.4	672.	684.( 5.)	784.( 7.)	-33.	-33.( 6.)	-33.( 4.)
1795.80189	3	5	5	0	5	4	1	1.06E-01	2	-2.4	646.	660.( 14.)	755.( 20.)	-54.	-54.( 4.)	-62.( 4.)
1796.02647	2	5	5	1	5	4	2	3.52E-02	2	-2.8	658.	685.( 7.)	785.( 18.)	-55.	-55.( 5.)	-51.( 14.)
1796.13245	2	6	5	2	6	4	3	9.73E-02	2	-2.8	630.	630.( 20.)	734.( 8.)	-46.	-46.( 4.)	-51.( 2.)
1796.29753	3	7	5	3	7	4	4	2.07E-02	2	-.5	609.	640.( 14.)	721.( 25.)	-54.	-54.( 1.)	-58.( 16.)
1796.92439	2	8	5	4	8	4	5	3.07E-02	3	-1.1	587.	620.( 20.)	700.( 11.)	-56.	-56.( 4.)	-58.( 4.)
1798.13384	5	11	3	9	11	2	10	1.36E-03	2	-1.5	364.	353.( 6.)	384.( 10.)	22.	22.( 5.)	37.( 7.)
1798.59091	3	9	5	5	9	4	6	4.33E-03	2	.7	560.	565.( 10.)	645.( 16.)	-51.	-51.( 2.)	-53.( 11.)
1799.61558	1	4	3	1	3	2	2	7.68E-01	1	.9	846.	860.( 12.)	958.( 5.)	22.	17.( 3.)	18.( 3.)
1801.32446	3	11	0	11	10	1	10	2.47E-01	3	.5	217.	224.( 15.)	240.( 15.)	-21.	-21.( 3.)	-17.( 2.)
1801.36212	5	11	1	11	10	0	10	8.35E-02	3	1.9	217.	224.( 15.)	240.( 15.)	-17.	-17.( 2.)	-14.( 2.)
1801.92946	3	10	5	6	10	4	7	4.59E-03	2	0	524.	534.( 14.)	570.( 40.)	-10.	-10.( 3.)	1.( 7.)
1802.47968	3	9	1	8	8	2	7	3.65E-01	1	-1.8	455.	464.( 5.)	514.( 5.)	-67.	-67.( 2.)	-75.( 2.)
1805.14638	2	5	3	2	5	0	5	3.11E-02	2	-2.0	911.	895.( 15.)	1008.( 10.)	51.	53.( 4.)	65.( 7.)
1807.70327	4	9	2	8	8	1	7	1.33E-01	3	5.7	521.	536.( 5.)	620.( 12.)	47.	47.( 4.)	62.( 3.)
1808.37200	6	12	4	9	12	3	10	6.85E-04	1	-1.5	376.	341.( 12.)	369.( 15.)	83.	83.( 4.)	112.( 2.)
1808.65476	4	11	1	10	11	0	11	5.03E-03	2	2.9	290.	282.( 8.)	301.( 12.)	-32.	-32.( 4.)	-33.( 1.)
1809.29490	2	11	2	10	11	1	11	1.68E-03	2	3.4	301.	288.( 7.)	314.( 12.)	-22.	-22.( 3.)	-18.( 2.)
1810.62815	3	5	3	3	4	2	2	5.04E-01	1	-2.0	875.	876.( 6.)	985.( 7.)	7.	7.( 3.)	7.( 3.)
1812.28213	3	9	2	7	8	3	6	1.11E-01	2	1.8	686.	705.( 12.)	798.( 7.)	-143.	-143.( 71.)	-167.( 83.)
1813.05041	7	12	2	10	12	1	11	3.75E-04	2	1.8	310.	308.( 12.)	342.( 5.)	-89.	-89.( 5.)	-101.( 6.)
1815.56806	4	12	5	6	12	4	9	3.71E-04	2	.3	413.	401.( 8.)	437.( 8.)	89.	89.( 2.)	117.( 5.)
1817.15170	4	11	4	7	10	5	6	1.60E-03	2	.7	653.	676.( 16.)	768.( 21.)	64.	64.( 6.)	90.( 5.)
1817.45168	2	12	0	12	11	1	11	3.25E-02	2	-.6	168.	153.( 9.)	166.( 5.)	-21.	-21.( 5.)	-30.( 8.)
1817.46881	5	12	1	12	11	0	11	9.90E-02	2	.9	167.	156.( 4.)	173.( 8.)	-22.	-22.( 3.)	-28.( 2.)
1817.67283	7	12	3	10	12	2	11	1.10E-03	3	1.8	297.	282.( 2.)	322.( 5.)	2.	2.( 3.)	14.( 1.)
1821.37402	5	10	3	7	9	4	6	4.55E-03	2	1.4	725.	673.( 11.)	754.( 14.)	-63.	-63.( 3.)	-74.( 5.)
1822.76062	3	10	1	9	9	2	8	5.70E-02	1	-.5	357.	366.( 10.)	406.( 8.)	-48.	-48.( 2.)	-55.( 2.)
1825.20154	2	6	3	4	5	2	3	8.82E-01	1	-2.0	885.	872.( 7.)	988.( 15.)	6.	6.( 2.)	6.( 3.)
1825.34876	3	10	2	9	9	1	8	1.72E-01	1	-.5	410.	401.( 7.)	458.( 6.)	34.	34.( 4.)	50.( 1.)
1828.20793	6	12	1	11	12	0	12	4.80E-04	2	.9	234.	224.( 2.)	260.( 10.)	-23.	-23.( 3.)	-20.( 1.)
1828.53175	2	12	2	11	12	1	12	1.45E-03	2	1.7	245.	233.( 7.)	273.( 14.)	-21.	-21.( 2.)	-15.( 7.)
1829.13028	3	5	2	3	4	1	4	4.17E-01	1	-1.4	952.	938.( 12.)	1043.( 7.)	41.	41.( 5.)	49.( 3.)
1830.13200	2	5	3	2	4	2	3	1.25E+00	1	-1.8	864.	845.( 3.)	955.( 7.)	29.	29.( 4.)	30.( 4.)
1833.27841	2	13	0	13	12	1	12	3.60E-02	2	1.3	132.	128.( 5.)	139.( 7.)	-20.	-20.( 1.)	-20.( 3.)
1833.28625	5	13	1	13	12	0	12	1.20E-02	2	1.3	129.	129.( 5.)	139.( 7.)	-22.	-22.( 6.)	-18.( 9.)
1834.14912	5	11	6	5	11	5	6	5.55E-04	1	.5	680.	690.( 26.)	770.( 15.)	-121.	-121.( 12.)	-125.( 12.)
1834.77804	5	13	2	11	13	1	12	2.74E-04	2	2.0	240.	235.( 4.)	280.( 15.)	-66.	-66.( 3.)	-67.( 34.)
1835.89297	3	6	3	3	6	0	6	4.65E-03	1	.8	891.	874.( 16.)	953.( 8.)	31.	29.( 4.)	31.( 4.)
1837.18093	3	7	3	5	6	2	4	1.68E-01	3	1.2	872.	844.( 18.)	954.( 18.)	-5.	-5.( 2.)	-1.( 4.)
1840.29815	5	10	6	4	10	5	5	5.65E-04	2	-.8	645.	635.( 15.)	752.( 9.)	-123.	-123.( 6.)	-129.( 4.)
1842.13068	1	11	1	10	10	2	9	6.95E-02	2	-1.8	278.	271.( 7.)	309.( 9.)	-39.	-39.( 4.)	-42.( 6.)
1843.39436	4	11	2	10	10	1	9	2.36E-02	2	-.2	314.	300.( 9.)	334.( 4.)	11.	11.( 2.)	18.( 2.)
1844.18061	2	4	4	1	3	3	0	1.91E+00	1	-2.7	708.	702.( 4.)	794.( 6.)	-33.	-33.( 2.)	-37.( 4.)
1844.39927	3	4	4	0	3	3	1	6.36E-01	1	-2.8	707.	698.( 6.)	770.( 10.)	-28.	-28.( 3.)	-26.( 5.)
1845.23063	5	8	6	2	8	5	3	3.35E-03	2	-1.1	570.	570.( 4.)	670.( 45.)	-92.	-92.( 11.)	-34.( 17.)
1845.36395	3	6	6	1	6	5	2	2.17E-02	3	-.6	510.	490.( 25.)	606.( 51.)	-52		

Table 2. continued

computed position	un	upper J K <sub>a</sub> K <sub>c</sub>	lower J K <sub>a</sub> K <sub>c</sub>	observed strength	%s (o-c)%	air b°(sm)	air b°(obs.)	N <sub>2</sub> b°(obs.)	air d°(sm)	air d°(obs.)	N <sub>2</sub> d°(obs.)
1847.37882	5	13 1 12	13 0 13	3.85E-04	4 -.9	195.	212. ( 6. )	221. ( 22. )	-20.	-20. ( 1. )	-12. ( 6. )
1847.78275	3	8 3 6	7 2 5	2.54E-01	0 -2.5	828.	793. ( 6. )	885. ( 4. )	21.	21. ( 3. )	26. ( 2. )
*1848.81510	5	14 1 14	13 0 13	1.60E-02	3 2.4	102.	96. ( 8. )	100. ( 6. )	-45.	-45. ( 9. )	-47. ( 4. )
1852.40497	2	5 4 1	5 1 4	7.65E-03	2 1.3	864.	880. ( 9. )	964. ( 20. )	42.	42. ( 2. )	45. ( 5. )
1854.12158	3	4 4 0	4 1 3	8.65E-04	2 2.5	900.	888. ( 20. )	987. ( 7. )	50.	51. ( 7. )	71. ( 4. )
1855.50527	5	14 2 12	14 1 13	1.99E-05	3 -.2	192.	177. ( 15. )	0. ( 0. )	-53.	-53. ( 1. )	-33. ( 4. )
1856.25968	2	6 4 2	6 1 5	3.38E-03	2 -.4	832.	823. ( 10. )	928. ( 5. )	40.	39. ( 3. )	43. ( 3. )
1856.91720	5	14 3 12	14 2 13	6.00E-05	3 1.1	190.	193. ( 6. )	224. ( 8. )	-20.	-20. ( 4. )	-11. ( 5. )
1857.62558	5	12 4 8	11 5 7	1.84E-04	2 .7	591.	584. ( 12. )	651. ( 19. )	34.	34. ( 6. )	70. ( 5. )
1858.51904	2	9 3 7	8 2 6	4.24E-02	2 -.4	750.	750. ( 15. )	860. ( 12. )	53.	53. ( 3. )	55. ( 3. )
1859.70361	3	11 3 8	10 4 7	5.65E-03	1 .1	659.	638. ( 10. )	711. ( 10. )	-149.	-149. ( 5. )	-171. ( 4. )
1860.91635	6	12 1 11	11 2 10	8.94E-03	1 2.4	216.	200. ( 12. )	227. ( 12. )	-33.	-33. ( 5. )	-33. ( 4. )
1861.53159	2	12 2 11	11 1 10	2.66E-02	2 1.5	236.	227. ( 5. )	249. ( 5. )	-10.	-10. ( 2. )	-3. ( 4. )
*1864.05585	5	15 0 15	14 1 14	4.66E-03	2 -.5	85.	90. ( 7. )	100. ( 3. )	-28.	-28. ( 3. )	-27. ( 1. )
1866.38083	3	6 3 3	5 2 4	1.82E-01	2 -1.4	873.	847. ( 11. )	955. ( 11. )	45.	45. ( 4. )	51. ( 3. )
1867.85277	3	5 4 2	4 3 1	3.94E-01	1 .8	764.	768. ( 7. )	890. ( 17. )	-23.	-23. ( 2. )	-25. ( 2. )
1868.05402	3	4 3 2	3 0 3	6.02E-02	2 -.2	958.	955. ( 12. )	1033. ( 23. )	84.	84. ( 2. )	76. ( 8. )
1868.72737	3	11 2 9	10 3 8	2.09E-02	1 -2.0	460.	475. ( 25. )	518. ( 5. )	-184.	-184. ( 10. )	-215. ( 108. )
1869.34560	2	5 4 1	4 3 2	1.15E+00	1 -1.6	714.	737. ( 5. )	825. ( 12. )	-25.	-25. ( 2. )	-29. ( 3. )
1870.80486	5	10 3 8	9 2 7	5.71E-02	4 2.0	646.	685. ( 15. )	768. ( 18. )	72.	72. ( 1. )	92. ( 4. )
1875.46504	8	15 2 13	15 1 14	1.20E-05	2 -1.5	163.	165. ( 9. )	171. ( 17. )	-48.	-39. ( 31. )	-51. ( 25. )
1876.63172	2	7 3 4	7 0 7	3.90E-03	2 -1.0	870.	873. ( 6. )	961. ( 7. )	7.	7. ( 2. )	10. ( 2. )
*1879.01941	10	16 1 16	15 0 15	1.28E-03	2 -.1	70.	72. ( 2. )	80. ( 4. )	-43.	-43. ( 2. )	-41. ( 1. )
1879.29777	3	13 1 12	12 2 11	8.75E-03	2 .1	168.	163. ( 18. )	163. ( 10. )	-33.	-33. ( 3. )	-29. ( 3. )
1879.59885	3	13 2 12	12 1 11	2.96E-03	3 1.5	176.	166. ( 9. )	170. ( 12. )	-24.	-24. ( 2. )	-17. ( 4. )
1884.56513	2	6 2 4	5 1 5	4.91E-02	2 -.5	911.	915. ( 20. )	1040. ( 30. )	26.	26. ( 3. )	33. ( 3. )
1885.30123	5	11 3 9	10 2 8	7.46E-03	2 1.3	530.	561. ( 8. )	638. ( 10. )	88.	88. ( 3. )	110. ( 3. )
1888.79980	5	8 4 4	8 1 7	1.12E-03	2 -.4	790.	753. ( 11. )	788. ( 6. )	70.	70. ( 7. )	65. ( 33. )
1889.56941	3	6 4 3	5 3 2	6.06E-01	1 -3.1	801.	806. ( 5. )	912. ( 7. )	-13.	-13. ( 2. )	-12. ( 2. )
1892.59805	7	12 2 10	11 3 9	2.56E-03	2 .7	357.	342. ( 9. )	384. ( 4. )	-140.	-140. ( 3. )	-159. ( 4. )
1894.65364	3	8 7 1	8 6 2	8.43E-04	3 -.6	447.	441. ( 6. )	516. ( 142. )	-118.	-116. ( 10. )	-85. ( 43. )
1894.68373	6	8 7 2	8 6 3	2.53E-03	2 -.5	458.	459. ( 8. )	508. ( 20. )	-100.	-95. ( 6. )	-91. ( 3. )
1895.19736	2	6 4 2	5 3 3	2.00E-01	3 -2.3	726.	731. ( 7. )	826. ( 5. )	-11.	-11. ( 4. )	-10. ( 5. )
1895.73836	7	10 7 4	10 6 5	5.06E-04	1 -.3	472.	469. ( 4. )	519. ( 30. )	-96.	-94. ( 4. )	-104. ( 52. )
1897.37245	6	14 1 13	13 2 12	8.88E-04	2 .8	131.	132. ( 7. )	145. ( 5. )	-39.	-39. ( 3. )	-36. ( 1. )
1897.52129	3	14 2 13	13 1 12	2.65E-03	2 -.3	131.	131. ( 9. )	141. ( 14. )	-31.	-31. ( 3. )	-26. ( 3. )
1898.66586	4	13 4 9	12 5 8	1.65E-04	1 -2.3	513.	515. ( 4. )	577. ( 10. )	-60.	-60. ( 5. )	-66. ( 3. )
1901.75954	7	12 3 10	11 2 9	7.73E-03	2 -.4	415.	422. ( 6. )	471. ( 8. )	74.	74. ( 4. )	98. ( 2. )
1904.35493	3	5 3 3	4 0 4	2.35E-02	2 .9	905.	907. ( 15. )	1005. ( 40. )	47.	47. ( 1. )	52. ( 2. )
1907.95904	2	7 4 4	6 3 3	9.80E-02	2 -1.2	820.	822. ( 6. )	925. ( 11. )	-6.	-6. ( 2. )	-5. ( 3. )
1909.96388	2	7 3 4	6 2 5	1.90E-01	2 -2.0	865.	855. ( 20. )	961. ( 20. )	43.	43. ( 3. )	53. ( 3. )
1914.58172	4	13 2 11	12 3 10	2.37E-03	2 -1.9	271.	264. ( 3. )	292. ( 5. )	-101.	-101. ( 2. )	-113. ( 1. )
1915.19562	5	15 1 14	14 2 13	7.35E-04	3 1.5	102.	105. ( 3. )	113. ( 4. )	-39.	-39. ( 2. )	-35. ( 2. )
1915.27037	5	15 2 14	14 1 13	2.46E-04	2 1.9	99.	104. ( 4. )	116. ( 5. )	-39.	-39. ( 3. )	-37. ( 2. )
1918.00673	2	5 5 1	4 4 0	2.33E-01	5 -3.3	559.	567. ( 8. )	650. ( 25. )	-60.	-56. ( 30. )	-77. ( 45. )
1918.03536	3	5 5 0	4 4 1	7.08E-01	4 -2.0	596.	562. ( 7. )	625. ( 15. )	-67.	-67. ( 4. )	-42. ( 22. )
1919.51338	7	13 3 11	12 2 10	8.10E-04	2 -.2	313.	294. ( 4. )	337. ( 12. )	43.	43. ( 3. )	61. ( 1. )
1919.68674	4	9 4 5	9 1 8	9.66E-04	1 -.7	783.	761. ( 11. )	875. ( 13. )	66.	65. ( 6. )	76. ( 10. )
1922.34084	2	8 4 5	7 3 4	1.26E-01	2 -2.3	820.	817. ( 15. )	925. ( 9. )	-20.	-20. ( 2. )	-22. ( 3. )
1923.16046	2	7 4 3	6 3 4	2.69E-01	0 -3.1	740.	722. ( 13. )	812. ( 4. )	14.	14. ( 3. )	18. ( 3. )
1925.06982	3	5 4 2	5 1 5	2.73E-04	1 3.1	851.	869. ( 28. )	914. ( 7. )	44.	41. ( 21. )	40. ( 3. )
1926.72595	5	8 3 5	8 0 8	2.74E-04	2 -.6	842.	885. ( 17. )	943. ( 19. )	17.	20. ( 10. )	17. ( 11. )
1927.85952	3	13 3 10	12 4 9	6.57E-04	2 -.6	470.	488. ( 8. )	553. ( 5. )	-244.	-244. ( 5. )	-286. ( 4. )
1932.80268	9	16 1 15	15 2 14	5.96E-05	2 -.8	79.	87. ( 3. )	100. ( 6. )	-43.	-43. ( 6. )	-40. ( 1. )
1932.84086	7	16 2 15	15 1 14	1.84E-04	2 2.0	77.	85. ( 3. )	97. ( 2. )	-43.	-43. ( 4. )	-41. ( 0. )
1933.16536	4	9 4 6	8 3 5	1.70E-02	2 -2.1	801.	811. ( 14. )	915. ( 9. )	-42.	-42. ( 2. )	-49. ( 0. )
1935.32453	4	14 2 12	13 3 11	2.28E-04	1 -.1	206.	202. ( 2. )	230. ( 5. )	-77.	-77. ( 4. )	-82. ( 3. )
1937.94648	4	14 3 12	13 2 11	6.81E-04	3 -.8	231.	222. ( 4. )	250. ( 4. )	8.	8. ( 3. )	19. ( 3. )
1939.12449	3	9 5 4	9 2 7	5.28E-04	2 -.2	730.	727. ( 10. )	835. ( 7. )	68.	69. ( 6. )	78. ( 11. )
*1940.26746	6	8 8 1	8 7 2	5.57E-04	2 -1.6	377.	379. ( 6. )	438. ( 2. )	-124.	-125. ( 8. )	-146. ( 3. )
1941.62747	5	10 4 7	9 3 6	1.96E-02	2 -1.2	762.	754. ( 11. )	838. ( 5. )	-36.	-36. ( 4. )	-37. ( 12. )
1942.51607	2	6 5 2	5 4 1	3.71E-01	1 -3.8	624.	622. ( 10. )	702. ( 7. )	-69.	-69. ( 3. )	-78. ( 3. )
1942.76526	2	6 5 1	5 4 2	1.27E-01	2 -1.1	582.	603. ( 8. )	683. ( 10. )	-63.	-63. ( 4. )	-74. ( 2. )
1945.34017	2	7 2 5	6 1 6	4.93E-02	2 .5	851.	853. ( 11. )	949. ( 35. )	37.	37. ( 4. )	46. ( 7. )
1946.36431	2	6 3 4	5 0 5	4.96E-02	1 .0	839.	830. ( 20. )	930. ( 15. )	51.	51. ( 4. )	58. ( 7. )
1949.24981	2	11 4 8	10 3 7	2.36E-03	2 -.2	704.	675. ( 11. )	756. ( 6. )	36.	36. ( 2. )	50. ( 6. )
1949.43208	3	10 5 5	10 2 8	7.70E-05	4 -.3	690.	691. ( 19. )	735. ( 30. )	98.	103. ( 32. )	111. ( 111. )
1950.10619	2	6 5 1	6 2 4	1.60E-04	1 3.6	808.	808. ( 15. )	870. ( 30. )	3.	-1. ( 6. )	9. ( 1. )
1950.22036	7	17 1 16	16 2 15	4.08E-05	2 -.2	60.	56. ( 4. )	62. ( 7. )	-44.	-44. ( 3. )	-44. ( 3. )
1950.24008	11	17 2 16	16 1 15	1.35E-05	3 -.8	63.	58. ( 8. )	55. ( 5. )	-43.	-43. ( 6. )	-40. ( 3. )
1951.12911	3	6 4 3	6 1 6	6.23E-04	1 .7	810.	804. ( 14. )	878. ( 4. )	38.	35. ( 6. )	40. ( 1. )
1954.99589	5	8 4 4	7 3 5	3.45E-02	2 -1.5	750.	724. ( 20. )	825. ( 35. )	66.	66. ( 6. )	82. ( 4. )
1955.25033	8	15 2 13	14 3 12	1.73E-04	1 -.6	159.	156. ( 7. )	176. ( 27. )	-63.	-63. ( 7. )	-67. ( 5. )
1956.23338	2	4 4 1	3 1 2	2.87E-03	2 3.9	893.	916. ( 14. )	1002. ( 5. )	45.	45. ( 5. )	45. ( 3. )
1956.64014	10	15 3 13	14 2 12	5.92E-05	1 1.8	169.	172. ( 7. )	178. ( 10. )	-23.	-23. ( 5. )	-11. ( 3. )

Table 2. continued

computed position	un	upper J K <sub>a</sub> K <sub>c</sub>	lower J K <sub>a</sub> K <sub>c</sub>	observed strength	t <sub>s</sub>	(o-c) <sub>t</sub>	air b°(sm)	air b°(obs.)	N <sub>2</sub> b°(obs.)	air d°(sm)	air d°(obs.)	N <sub>2</sub> d°(obs.)
1957.65551	6	12 4 9	11 3 8	2.34E-03	2	-4.	628.	649. ( 5.)	738. ( 7.)	89.	89. ( 4.)	116. ( 6.)
1959.63238	3	5 5 0	5 2 3	1.64E-04	1	6.6	865.	862. ( 12.)	960. ( 30.)	20.	15. ( 4.)	38. ( 18.)
1961.18139	5	8 3 5	7 2 6	1.87E-02	2	-1.0	834.	850. ( 20.)	944. ( 18.)	45.	45. ( 6.)	53. ( 3.)
1966.26124	3	7 5 3	6 4 2	6.16E-02	2	.6	687.	682. ( 12.)	754. ( 27.)	-64.	-64. ( 3.)	-66. ( 4.)
1967.44231	3	7 5 2	6 4 3	1.84E-01	2	.3	581.	615. ( 25.)	708. ( 11.)	-64.	-64. ( 5.)	-70. ( 4.)
1968.17070	2	13 4 10	12 3 9	2.35E-04	2	-3.	536.	547. ( 25.)	606. ( 12.)	123.	123. ( 15.)	166. ( 83.)
1974.60884	35	16 2 14	15 3 13	1.30E-05	4	-2.6	129.	142. ( 15.)	159. ( 5.)	-58.	-58. ( 11.)	-53. ( 12.)
1975.34794	11	16 3 14	15 2 13	3.96E-05	2	-1.1	126.	128. ( 3.)	137. ( 6.)	-37.	-37. ( 1.)	-30. ( 2.)
1976.19825	3	5 4 2	4 1 3	3.02E-03	2	3.6	900.	883. ( 11.)	980. ( 9.)	53.	53. ( 5.)	65. ( 3.)
1981.32806	4	14 4 11	13 3 10	1.91E-04	1	-.2	435.	428. ( 15.)	510. ( 16.)	130.	130. ( 5.)	166. ( 0.)
1982.19772	5	15 3 12	14 4 11	4.45E-05	2	-1.2	250.	251. ( 12.)	280. ( 10.)	-180.	-180. ( 7.)	-230. ( 23.)
1983.02876	2	7 4 4	7 1 7	1.01E-04	1	.1	773.	741. ( 17.)	827. ( 40.)	62.	51. ( 16.)	79. ( 48.)
*1984.45515	9	9 9 0	9 8 1	5.45E-05	2	-2.5	327.	325. ( 33.)	383. ( 38.)	-131.	-134. ( 67.)	-133. ( 66.)
*1986.65831	7	10 9 2	10 8 3	3.23E-05	2	-1.0	310.	310. ( 12.)	328. ( 20.)	-90.	-91. ( 16.)	-99. ( 46.)
1987.34013	3	4 4 0	3 1 3	3.45E-04	4	2.2	925.	927. ( 28.)	1025. ( 19.)	50.	50. ( 10.)	47. ( 14.)
1988.39582	2	8 5 4	7 4 3	7.70E-02	2	-1.0	739.	707. ( 10.)	800. ( 8.)	-50.	-47. ( 2.)	-48. ( 3.)
1992.38811	4	8 5 3	7 4 4	2.53E-02	3	-1.6	588.	624. ( 17.)	708. ( 17.)	-60.	-60. ( 7.)	-65. ( 6.)
1992.65038	4	9 4 5	8 3 6	3.15E-02	2	-3.2	754.	763. ( 25.)	840. ( 18.)	100.	100. ( 4.)	126. ( 3.)
1993.25783	3	7 3 5	6 0 6	8.72E-03	2	2.0	766.	786. ( 15.)	856. ( 10.)	57.	57. ( 3.)	71. ( 2.)
1998.92395	3	6 4 3	5 1 4	1.45E-02	2	1.0	879.	876. ( 18.)	962. ( 8.)	44.	44. ( 2.)	52. ( 1.)
1999.94585	2	6 5 2	6 2 5	1.61E-04	1	4.9	750.	746. ( 38.)	865. ( 20.)	18.	13. ( 5.)	44. ( 11.)
2007.70022	3	9 5 5	8 4 4	9.73E-03	1	-.0	768.	773. ( 17.)	862. ( 25.)	-61.	-61. ( 4.)	-63. ( 0.)
2009.33372	4	8 2 6	7 1 7	5.28E-03	2	1.4	775.	782. ( 5.)	854. ( 21.)	-11.	-11. ( 3.)	-4. ( 1.)
2016.79796	4	7 6 2	6 5 1	3.00E-02	2	-1.3	478.	490. ( 20.)	548. ( 34.)	-124.	-124. ( 15.)	-104. ( 39.)
2016.83473	2	7 6 1	6 5 2	8.90E-02	2	-2.4	489.	490. ( 13.)	557. ( 8.)	-99.	-99. ( 7.)	-104. ( 13.)
2018.33745	3	9 5 4	8 4 5	2.80E-02	2	-1.3	600.	590. ( 25.)	685. ( 13.)	-37.	-37. ( 4.)	-37. ( 3.)
2019.07018	3	9 3 6	8 2 7	1.45E-02	2	-.9	781.	824. ( 17.)	922. ( 10.)	64.	64. ( 7.)	77. ( 1.)
2020.53476	2	8 4 5	8 1 8	9.68E-05	2	-5.5	736.	720. ( 41.)	814. ( 25.)	46.	53. ( 11.)	57. ( 10.)
2023.03009	3	10 5 6	9 4 5	9.65E-03	2	-1.3	767.	781. ( 6.)	891. ( 8.)	-70.	-70. ( 2.)	-76. ( 0.)
2026.60217	2	7 4 4	6 1 5	4.94E-03	2	2.3	833.	816. ( 8.)	906. ( 7.)	38.	38. ( 3.)	45. ( 2.)
2027.02410	2	5 4 1	4 1 4	1.78E-03	2	3.0	876.	885. ( 12.)	970. ( 14.)	45.	45. ( 5.)	52. ( 9.)
2034.05610	5	11 5 7	10 4 6	9.95E-04	2	-.2	733.	791. ( 31.)	862. ( 18.)	-83.	-83. ( 7.)	-97. ( 6.)
2037.50673	4	10 4 6	9 3 7	2.75E-03	2	.6	748.	764. ( 10.)	876. ( 8.)	115.	115. ( 6.)	143. ( 4.)
2041.28838	5	8 6 3	7 5 2	3.81E-02	2	-1.6	526.	517. ( 15.)	588. ( 9.)	-93.	-93. ( 5.)	-108. ( 5.)
2041.49552	5	8 6 2	7 5 3	1.27E-02	2	-1.6	538.	538. ( 20.)	588. ( 6.)	-88.	-88. ( 5.)	-99. ( 5.)
2043.94903	3	8 3 6	7 0 7	1.08E-02	2	-.3	690.	696. ( 12.)	769. ( 6.)	65.	65. ( 1.)	82. ( 1.)
2046.51581	3	10 5 5	9 4 6	2.98E-03	2	-.3	613.	571. ( 6.)	637. ( 4.)	16.	16. ( 3.)	25. ( 5.)
2046.79557	7	13 5 9	12 4 8	7.23E-05	2	-2.4	585.	522. ( 19.)	676. ( 15.)	-85.	-85. ( 43.)	-97. ( 97.)
2051.55618	40	14 5 10	13 4 9	5.45E-05	2	-.3	492.	520. ( 30.)	629. ( 40.)	75.	75. ( 37.)	57. ( 29.)
2060.48338	2	8 4 5	7 1 6	9.60E-03	2	1.4	766.	767. ( 16.)	857. ( 8.)	62.	62. ( 2.)	73. ( 1.)
*2064.85367	5	7 7 0	6 6 1	4.90E-02	4	-3.5	309.	310. ( 20.)	366. ( 46.)	-110.	-106. ( 41.)	-113. ( 2.)
2065.01825	3	9 6 4	8 5 3	4.87E-03	3	-.2	566.	563. ( 19.)	624. ( 6.)	-98.	-98. ( 5.)	-113. ( 2.)
2065.84659	9	9 6 3	8 5 4	1.45E-02	1	-.8	553.	546. ( 15.)	592. ( 16.)	-100.	-100. ( 4.)	-108. ( 2.)
2072.53999	2	6 4 2	5 1 5	5.03E-04	2	3.6	849.	831. ( 26.)	918. ( 7.)	50.	50. ( 10.)	54. ( 3.)
2074.23540	3	9 2 7	8 1 8	4.78E-03	2	-.2	690.	707. ( 16.)	772. ( 8.)	-42.	-42. ( 5.)	-42. ( 2.)
2078.56807	3	11 5 6	10 4 7	2.38E-03	3	-.1	621.	584. ( 18.)	638. ( 4.)	95.	95. ( 12.)	143. ( 5.)
2081.87346	5	10 3 7	9 2 8	1.15E-03	2	-.3	708.	712. ( 10.)	798. ( 11.)	43.	43. ( 6.)	65. ( 2.)
2087.40768	4	10 6 5	9 5 4	4.86E-03	2	-1.0	600.	598. ( 13.)	674. ( 13.)	-111.	-111. ( 4.)	-123. ( 2.)
2089.74226	4	11 4 7	10 3 8	1.72E-03	3	-.4	727.	748. ( 15.)	857. ( 20.)	111.	111. ( 4.)	142. ( 11.)
2090.02279	4	10 6 4	9 5 5	1.63E-03	1	-.1	536.	545. ( 13.)	637. ( 11.)	-85.	-85. ( 13.)	-74. ( 9.)
2090.10066	6	8 7 2	7 6 1	1.58E-02	2	-1.4	388.	380. ( 40.)	403. ( 20.)	-81.	-89. ( 11.)	-99. ( 50.)
2097.36710	2	9 3 7	8 0 8	1.28E-03	3	-.2	613.	610. ( 8.)	683. ( 5.)	51.	51. ( 3.)	71. ( 4.)
2100.43270	4	9 4 6	8 1 7	1.49E-03	2	2.1	686.	677. ( 5.)	776. ( 6.)	96.	96. ( 2.)	126. ( 3.)
2105.78077	3	5 5 0	4 2 3	2.04E-04	2	4.6	822.	833. ( 11.)	955. ( 29.)	19.	19. ( 4.)	36. ( 39.)
2106.34656	2	6 5 2	5 2 3	6.81E-04	1	5.1	845.	845. ( 12.)	942. ( 16.)	16.	16. ( 5.)	22. ( 14.)
2107.54642	5	11 6 6	10 5 5	4.87E-04	2	-.2	628.	637. ( 13.)	721. ( 6.)	-116.	-116. ( 5.)	-138. ( 5.)
2114.42562	3	11 6 5	10 5 6	1.45E-03	2	1.1	498.	499. ( 4.)	562. ( 13.)	-88.	-88. ( 4.)	-91. ( 5.)
2114.98300	4	9 7 3	8 6 2	2.00E-03	3	-.3	438.	457. ( 10.)	543. ( 54.)	-96.	-103. ( 17.)	-32. ( 16.)
2115.01602	3	9 7 2	8 6 3	5.98E-03	4	-.6	438.	431. ( 16.)	462. ( 9.)	-96.	-101. ( 10.)	-54. ( 34.)
2116.22382	2	12 5 7	11 4 8	1.76E-04	3	1.4	622.	590. ( 12.)	679. ( 25.)	148.	148. ( 38.)	205. ( 5.)
2121.26793	3	7 5 3	6 2 4	3.54E-04	2	3.9	845.	831. ( 25.)	935. ( 8.)	15.	-2. ( 15.)	15. ( 5.)
2124.29003	5	12 6 7	11 5 6	3.85E-04	4	-.3	654.	650. ( 16.)	748. ( 16.)	-136.	-136. ( 12.)	-146. ( 4.)
2124.88680	2	7 4 3	6 1 6	7.58E-04	2	1.9	838.	809. ( 14.)	886. ( 5.)	52.	52. ( 5.)	65. ( 5.)
*2136.14332	6	8 8 1	7 7 0	7.56E-03	4	-1.2	257.	256. ( 7.)	277. ( 6.)	-105.	-104. ( 4.)	-110. ( 1.)
2137.22310	2	8 5 4	7 2 5	1.18E-03	2	1.6	825.	790. ( 10.)	909. ( 21.)	17.	17. ( 8.)	28. ( 8.)
2138.18844	5	10 2 8	9 1 9	4.50E-04	2	-.9	601.	617. ( 23.)	669. ( 9.)	-66.	-66. ( 8.)	-69. ( 2.)
2139.32836	5	10 7 4	9 6 3	2.00E-03	2	-.6	459.	459. ( 11.)	508. ( 10.)	-107.	-107. ( 4.)	-117. ( 6.)
2139.47904	6	10 7 3	9 6 4	6.74E-04	2	-.6	459.	466. ( 16.)	510. ( 8.)	-118.	-118. ( 13.)	-128. ( 6.)
2139.81422	10	12 6 6	11 5 7	1.23E-04	3	-.6	447.	440. ( 7.)	509. ( 4.)	-50.	-50. ( 5.)	-43. ( 6.)
2145.46700	5	10 4 7	9 1 8	1.55E-03	2	-.1	600.	585. ( 13.)	677. ( 9.)	130.	130. ( 4.)	169. ( 5.)
2147.40553	3	11 3 8	10 2 9	7.57E-04	2	-.3	622.	600. ( 15.)	685. ( 9.)	-26.	-26. ( 2.)	-30. ( 15.)
2148.34183	4	12 4 8	11 3 9	1.06E-04	2	1.5	690.	680. ( 40.)	806. ( 29.)	129.	129. ( 14.)	164. ( 23.)
2152.55801	5	10 3 8	9 0 9	1.18E-03	2	-1.4	540.	523. ( 10.)	587. ( 6.)	39.	39. ( 6.)	59. ( 8.)
2156.56407	3	9 5 5	8 2 6	3.30E-04	3	3.2	783.	800. ( 20.)	875. ( 35.)	57.	57. ( 7.)	53. ( 44.)
*2161.72616	5	9 8 1	8 7 2	2.70E-03	4	-4.8	288.	310. ( 2.)	347. ( 16.)	-116.	-116. ( 3.)	-118. ( 4.)

Table 2. continued

computed position	un	upper				lower				observed strength	air			$N_2$		air			$N_2$	
		J	K <sub>a</sub>	K <sub>c</sub>	J	K <sub>a</sub>	K <sub>c</sub>	t <sub>s</sub>	(o-c)t		b <sup>0</sup> (sm)	b <sup>0</sup> (obs.)	b <sup>0</sup> (obs.)	d <sup>0</sup> (sm)	d <sup>0</sup> (obs.)	d <sup>0</sup> (obs.)	d <sup>0</sup> (obs.)	d <sup>0</sup> (obs.)		
2162.88970	6	11	7	5	10	6	4	2.00E-04	3	.7	455.	450.( 7.)	531.( 8.)	-123.	-123.( 6.)	-126.( 9.)				
2163.43047	9	11	7	4	10	6	5	6.00E-04	3	.8	455.	436.( 7.)	495.( 12.)	-113.	-113.( 1.)	-119.( 2.)				
2167.34028	4	13	6	7	12	5	8	8.08E-05	2	.9	395.	397.( 8.)	434.( 20.)	39.	39.( 14.)	39.( 14.)				
2171.25571	3	7	5	2	6	2	5	3.47E-04	2	1.5	713.	752.( 10.)	826.( 16.)	36.	30.( 13.)	48.( 7.)				
2181.34393	3	10	5	6	9	2	7	5.70E-04	2	1.7	722.	721.( 5.)	837.( 6.)	85.	78.( 14.)	91.( 7.)				
2185.27811	4	12	7	6	11	6	5	1.59E-04	2	1.9	441.	459.( 6.)	496.( 15.)	-130.	-130.( 20.)	-125.( 24.)				
2200.30574	3	11	2	9	10	1	10	3.39E-04	2	-5.1	515.	490.( 10.)	555.( 7.)	-86.	-86.( 2.)	-79.( 4.)				
*2205.21741	9	9	9	0	8	8	1	8.72E-04	2	-1.0	193.	202.( 4.)	216.( 7.)	-98.	-97.( 3.)	-101.( 2.)				
2208.73765	5	11	3	9	10	0	10	1.05E-04	2	-4.5	472.	466.( 5.)	531.( 30.)	26.	22.( 31.)	37.( 23.)				
2211.63114	5	11	8	3	10	7	4	2.04E-04	2	.3	351.	352.( 25.)	393.( 7.)	-82.	-77.( 17.)	-83.( 42.)				
*2231.13704	6	10	9	2	9	8	1	2.82E-04	2	-.2	236.	235.( 9.)	264.( 20.)	-103.	-97.( 10.)	-110.( 5.)				
2235.64051	7	12	8	5	11	7	4	5.43E-05	3	4.2	376.	369.( 20.)	434.( 20.)	-88.	-124.( 62.)	-129.( 65.)				
2246.03099	6	12	4	9	11	1	10	1.06E-04	1	.2	437.	412.( 15.)	444.( 8.)	117.	117.( 10.)	151.( 30.)				
*2256.61778	9	11	9	2	10	8	3	8.00E-05	2	.4	273.	275.( 15.)	322.( 12.)	-105.	-101.( 2.)	-110.( 2.)				
2265.31396	8	12	3	10	11	0	11	7.70E-05	2	-1.9	410.	410.( 20.)	0.( 0.)	-17.	0.( 0.)	0.( 0.)				
*2271.72348	15	10	10	1	9	9	0	7.10E-05	3	-5.4	158.	150.( 15.)	185.( 17.)	-113.	-109.( 54.)	-98.( 1.)				

$b^0$  and  $d^0$  in  $\text{cm}^{-1}/\text{atm.} \times 10^4$  at 296 K.

Strengths in  $\text{cm}^{-2}/\text{atm.}$  at 296K,  $t_s$  is the estimated uncertainty in the observed strength in percent,  $(o-c)t$  is the percent difference between the observed and computed strength. Computed strength derived from parameters given in ref. 13. Positions and un in  $\text{cm}^{-1}$ . un is the estimated uncertainty in the line positions  $\times 10^5$ . The computed values are derived from the energy levels given in Table 2 in ref 13 along with the estimated uncertainties in the levels.

\*asterisks denote doubled absorptions with the quantum assignment given for the stronger transition.

The strength given represents the sum of the strengths of the two comparable transitions.

$b^0(\text{sm})$  and  $d^0(\text{sm})$  are smoothed values derived from hand plots of the observed coefficients

Values given within parentheses are estimated uncertainties in the last digits.

Table 3. Line positions, strengths, air and N<sub>2</sub>-broadened width coefficients, (HWHM) b°, and pressure-induced frequency shift coefficients, d°, for the (000)-(000) band of H<sub>2</sub><sup>16</sup>O.

computed position	un	upper J	K <sub>a</sub>	K <sub>c</sub>	lower J	K <sub>a</sub>	K <sub>c</sub>	observed strength	% (o-c)	air b° (cm)	b° (obs.)	N <sub>2</sub> b° (obs.)	air d° (cm)	d° (obs.)	N <sub>2</sub> d° (obs.)	
608.66641	2	9	7	2	9	2	7	1.90E-04	4	- .9	750.	766. ( 10. )	839. ( 84. )	69.	69. ( 35. )	39. ( 20. )
612.95006	1	7	5	3	6	0	6	5.23E-03	2	2.4	880.	865. ( 20. )	861. ( 66. )	66.	68. ( 12. )	52. ( 8. )
614.57693	8	15	5	10	14	4	11	6.20E-04	5	-2.7	534.	555. ( 25. )	632. ( 18. )	112.	112. ( 6. )	136. ( 13. )
616.07267	0	9	4	5	8	1	8	4.18E-02	3	-1.1	840.	865. ( 20. )	998. ( 91. )	12.	12. ( 5. )	25. ( 10. )
619.19842	3	11	6	5	11	1	10	2.41E-04	5	-1.8	670.	637. ( 10. )	755. ( 76. )	108.	108. ( 54. )	111. ( 56. )
620.57700	2	12	6	7	11	3	8	1.22E-02	3	-1.5	738.	732. ( 9. )	850. ( 60. )	126.	127. ( 15. )	133. ( 6. )
626.32250	5	13	5	9	12	2	10	4.05E-03	4	- .5	476.	445. ( 4. )	532. ( 35. )	200.	200. ( 5. )	248. ( 9. )
632.76969	5	14	4	10	13	3	11	1.23E-03	3	- .5	566.	559. ( 16. )	605. ( 20. )	-80.	-80. ( 5. )	-85. ( 6. )
633.08971	5	12	2	10	11	1	11	1.85E-02	4	1.3	436.	447. ( 31. )	483. ( 25. )	-11.	-11. ( 4. )	-22. ( 9. )
637.03397	1	7	7	1	6	4	2	3.08E-03	2	3.4	724.	726. ( 6. )	811. ( 46. )	-24.	-22. ( 6. )	-31. ( 5. )
642.23156	3	13	6	8	12	3	9	1.68E-03	4	2.6	693.	711. ( 25. )	783. ( 66. )	163.	164. ( 4. )	195. ( 9. )
644.31998	4	10	5	5	9	2	8	1.36E-02	4	-1.8	729.	725. ( 25. )	844. ( 80. )	132.	97. ( 49. )	161. ( 11. )
645.60042	1	6	6	1	5	1	4	1.05E-03	3	14.7	888.	875. ( 15. )	975. ( 30. )	46.	53. ( 6. )	47. ( 19. )
651.58021	5	13	4	10	12	1	11	6.05E-03	3	- .1	369.	375. ( 24. )	410. ( 35. )	91.	91. ( 13. )	113. ( 2. )
671.36023	5	14	5	10	13	2	11	3.40E-03	3	.2	395.	394. ( 39. )	434. ( 3. )	162.	100. ( 50. )	209. ( 15. )
671.88534	5	11	5	6	11	0	11	1.30E-04	3	-4.3	681.	681. ( 20. )	877. ( 88. )	13.	13. ( 6. )	39. ( 20. )
673.28399	0	7	6	2	6	1	5	1.18E-03	4	-2.5	858.	865. ( 35. )	892. ( 10. )	11.	11. ( 5. )	68. ( 21. )
678.80772	3	9	7	3	8	4	4	4.49E-03	3	- .1	807.	781. ( 33. )	880. ( 30. )	-33.	-33. ( 3. )	-21. ( 8. )
687.87938	2	9	7	2	8	4	5	1.37E-02	2	.3	667.	644. ( 26. )	743. ( 40. )	-53.	-52. ( 4. )	-60. ( 8. )
689.03700	3	13	2	11	12	1	12	1.95E-02	4	3.8	367.	358. ( 30. )	380. ( 40. )	-5.	-12. ( 12. )	-4. ( 1. )
690.22007	4	13	3	11	12	0	12	6.42E-03	3	2.6	356.	372. ( 24. )	392. ( 6. )	34.	34. ( 3. )	43. ( 4. )
693.11707	6	15	4	11	14	3	12	8.80E-04	3	1.5	484.	476. ( 13. )	541. ( 14. )	-105.	-105. ( 2. )	-125. ( 5. )
694.10992	3	10	7	4	9	4	5	9.26E-03	2	- .5	796.	826. ( 29. )	904. ( 15. )	-47.	-48. ( 16. )	-51. ( 7. )
696.24305	3	10	4	6	9	1	9	4.20E-03	4	2.0	837.	844. ( 15. )	956. ( 28. )	11.	11. ( 9. )	16. ( 1. )
697.05433	6	14	3	11	13	2	12	1.82E-03	4	4.1	364.	372. ( 8. )	412. ( 7. )	-56.	-56. ( 1. )	-61. ( 2. )
703.71286	4	14	4	11	13	1	12	5.30E-03	3	1.4	311.	317. ( 17. )	340. ( 10. )	74.	74. ( 6. )	84. ( 7. )
707.39739	0	8	6	3	7	1	6	5.75E-03	5	-5.6	770.	771. ( 10. )	872. ( 6. )	30.	44. ( 22. )	50. ( 2. )
713.48381	3	10	7	3	9	4	6	3.13E-03	2	.0	602.	599. ( 10. )	679. ( 6. )	-56.	-57. ( 4. )	-61. ( 3. )
713.79161	7	12	7	6	11	4	7	2.48E-03	3	- .2	716.	727. ( 9. )	830. ( 4. )	-56.	-57. ( 2. )	-86. ( 2. )
718.65710	5	15	5	11	14	2	12	2.81E-04	3	.6	324.	311. ( 6. )	342. ( 5. )	127.	127. ( 3. )	154. ( 6. )
721.42241	5	13	7	7	12	4	8	3.48E-04	2	.0	668.	640. ( 3. )	724. ( 7. )	-33.	-35. ( 9. )	-28. ( 3. )
729.20740	4	8	8	1	7	5	2	2.05E-03	2	1.5	624.	628. ( 15. )	723. ( 7. )	-70.	-69. ( 2. )	-79. ( 3. )
729.39620	4	8	8	0	7	5	3	6.69E-04	2	.3	591.	597. ( 17. )	691. ( 8. )	-66.	-66. ( 6. )	-74. ( 8. )
730.54429	5	14	7	8	13	4	9	3.81E-04	3	- .2	626.	620. ( 25. )	660. ( 15. )	92.	90. ( 6. )	105. ( 2. )
730.91712	1	9	5	5	8	0	8	2.53E-03	3	1.8	747.	737. ( 11. )	829. ( 16. )	59.	59. ( 3. )	64. ( 5. )
740.56978	3	11	7	4	10	4	7	5.05E-03	2	- .5	534.	555. ( 18. )	621. ( 5. )	-35.	-34. ( 4. )	-38. ( 2. )
742.06719	7	16	6	11	15	3	12	9.10E-05	3	-1.5	351.	350. ( 20. )	387. ( 24. )	194.	192. ( 10. )	243. ( 6. )
742.43332	5	12	6	6	11	3	9	1.58E-03	3	- .9	590.	583. ( 6. )	668. ( 21. )	154.	155. ( 2. )	188. ( 5. )
744.21082	3	14	2	12	13	1	13	2.00E-03	2	1.7	309.	298. ( 6. )	332. ( 3. )	11.	11. ( 4. )	14. ( 1. )
744.81349	5	14	3	12	13	0	13	6.05E-03	2	2.6	309.	310. ( 9. )	338. ( 5. )	30.	30. ( 3. )	37. ( 2. )
748.35515	1	9	6	4	8	1	7	1.97E-03	3	2.1	722.	714. ( 7. )	801. ( 11. )	65.	65. ( 1. )	71. ( 10. )
751.18440	10	16	4	12	15	3	13	6.45E-05	2	2.3	395.	404. ( 3. )	444. ( 10. )	-97.	-97. ( 1. )	-115. ( 12. )
752.26468	5	15	3	12	14	2	13	1.40E-03	3	2.0	297.	296. ( 5. )	333. ( 3. )	-30.	-30. ( 4. )	-33. ( 3. )
753.89345	6	9	8	2	8	5	3	9.56E-04	3	3.1	613.	603. ( 7. )	703. ( 10. )	-74.	-74. ( 3. )	-79. ( 4. )
754.63835	2	9	8	1	8	5	4	2.83E-03	2	1.2	597.	589. ( 17. )	665. ( 25. )	-68.	-55. ( 5. )	-87. ( 2. )
755.98148	10	15	4	12	14	1	13	4.65E-04	3	1.8	266.	262. ( 6. )	298. ( 5. )	53.	53. ( 3. )	70. ( 3. )
760.42313	5	10	6	5	10	1	10	3.70E-05	3	-1.3	689.	700. ( 25. )	767. ( 153. )	39.	39. ( 19. )	35. ( 35. )
761.47255	11	16	7	10	15	4	11	3.12E-05	4	.0	582.	572. ( 10. )	657. ( 36. )	173.	171. ( 11. )	211. ( 73. )
767.26368	20	16	5	12	15	2	13	1.87E-04	2	.2	264.	261. ( 7. )	283. ( 5. )	99.	99. ( 6. )	116. ( 2. )
768.94215	0	7	6	1	6	1	6	4.16E-04	3	-1.0	823.	811. ( 32. )	916. ( 12. )	28.	30. ( 10. )	28. ( 2. )
770.07498	6	12	7	5	11	4	8	7.37E-04	4	- .2	478.	482. ( 4. )	547. ( 12. )	23.	24. ( 4. )	31. ( 4. )
775.54906	10	12	5	7	11	2	10	1.19E-03	3	1.2	769.	763. ( 8. )	880. ( 10. )	66.	67. ( 5. )	78. ( 4. )
776.98647	5	10	8	3	9	5	4	2.26E-03	2	-.6	625.	631. ( 11. )	727. ( 8. )	-86.	-87. ( 5. )	-99. ( 1. )
779.30365	4	10	8	2	9	5	5	7.63E-04	2	.4	581.	569. ( 8. )	642. ( 10. )	-95.	-96. ( 4. )	-105. ( 1. )
784.45829	5	11	4	7	10	1	10	3.18E-03	3	- .2	821.	841. ( 12. )	936. ( 4. )	34.	34. ( 2. )	44. ( 4. )
793.90836	3	13	6	7	12	3	10	1.34E-03	2	-1.9	604.	618. ( 9. )	712. ( 9. )	164.	165. ( 3. )	197. ( 6. )
795.89343	5	10	6	5	9	1	8	3.78E-03	2	-.4	678.	671. ( 8. )	746. ( 12. )	89.	90. ( 3. )	113. ( 1. )
797.55589	6	11	8	4	10	5	5	4.51E-04	4	.7	650.	654. ( 6. )	777. ( 3. )	-109.	-111. ( 11. )	-124. ( 6. )
798.55045	1	10	5	6	9	0	9	3.50E-03	2	-.1	722.	725. ( 16. )	803. ( 8. )	69.	69. ( 5. )	87. ( 4. )
798.75853	5	15	2	13	14	1	14	1.72E-03	4	1.5	264.	263. ( 5. )	290. ( 4. )	17.	17. ( 2. )	22. ( 3. )
799.06549	5	15	3	13	14	0	14	5.84E-04	2	3.2	269.	264. ( 7. )	295. ( 4. )	31.	31. ( 3. )	36. ( 6. )
802.98996	6	13	7	6	12	4	9	7.85E-04	3	-.8	441.	437. ( 6. )	500. ( 4. )	90.	90. ( 5. )	111. ( 2. )
803.54638	3	11	8	3	10	5	6	1.35E-03	2	-.9	549.	560. ( 9. )	637. ( 7. )	-105.	-108. ( 8. )	-117. ( 4. )
805.99370	16	16	3	13	15	2	14	1.12E-04	2	2.1	245.	242. ( 4. )	277. ( 8. )	-11.	-11. ( 5. )	-8. ( 7. )
806.69564	8	17	4	3	16	3	14	3.76E-05	2	-.9	306.	305. ( 6. )	381. ( 1. )	-56.	-56. ( 10. )	-80. ( 17. )
808.03788	30	16	4	13	15	1	14	3.35E-04	2	2.1	232.	234. ( 6. )	262. ( 7. )	43.	43. ( 3. )	56. ( 1. )
808.28024	2	8	7	2	7	2	5	3.90E-04	3	-3.2	814.	813. (				

Table 3. continued

computed position	un	upper J	K <sub>a</sub>	K <sub>c</sub>	lower J	K <sub>a</sub>	K <sub>c</sub>	observed strength	ts	(o-c)†	air b <sup>o</sup> (sm)	N <sub>2</sub> b <sup>o</sup> (obs.)	air d <sup>o</sup> (sm)	N <sub>2</sub> d <sup>o</sup> (obs.)		
825.16270	1	8	6	2	7	1	7	1.66E-04	2	1.8	775.	781.( 8.)	33.	30.( 9.)	33.( 4.)	
827.11796	12	13	8	6	12	5	7	8.20E-05	3	-5.	695.	704.( 7.)	-89.	-80.( 11.)	-108.( 23.)	
827.67157	3	9	7	3	8	2	6	2.49E-04	2	-8.	750.	754.( 22.)	39.	42.( 8.)	47.( 33.)	
827.74378	6	12	8	4	11	5	7	2.16E-04	2	-3.	506.	526.( 12.)	-115.	-113.( 6.)	-130.( 17.)	
835.55296	5	14	8	7	13	5	8	8.31E-05	2	.2	689.	686.( 3.)	-108.	-105.( 5.)	-134.( 17.)	
839.87197	2	10	9	2	9	6	3	4.20E-04	2	-9.	508.	514.( 9.)	-88.	-88.( 9.)	-99.( 10.)	
840.00950	2	10	9	1	9	6	4	1.39E-04	3	-2.1	508.	490.( 12.)	-82.	-85.( 8.)	-79.( 20.)	
840.31789	12	14	7	7	13	4	10	7.68E-05	2	-5.	429.	414.( 10.)	158.	155.( 8.)	192.( 25.)	
841.90281	0	7	7	0	6	2	5	5.48E-05	4	-10.0	827.	829.( 27.)	10.	9.( 11.)	22.( 13.)	
849.57954	4	11	6	6	10	1	9	6.14E-04	5	.0	625.	617.( 11.)	114.	115.( 4.)	140.( 4.)	
852.42375	3	10	7	4	9	2	7	8.82E-04	2	1.9	736.	722.( 23.)	62.	65.( 5.)	68.( 2.)	
852.48896	7	13	8	5	12	5	8	2.55E-04	1	.1	459.	440.( 9.)	-78.	-78.( 6.)	-81.( 5.)	
852.75424	11	16	2	14	15	1	15	1.48E-04	3	-.1	231.	246.( 6.)	16.	16.( 7.)	22.( 2.)	
852.91119	6	16	3	14	15	0	15	4.50E-04	3	1.1	237.	239.( 3.)	29.	29.( 6.)	39.( 2.)	
853.37657	10	14	6	8	13	3	11	1.04E-04	2	.3	642.	633.( 27.)	157.	157.( 3.)	194.( 7.)	
854.58333	3	13	5	8	12	2	11	7.42E-04	3	-1.6	765.	784.( 9.)	82.	80.( 9.)	102.( 5.)	
858.54294	10	17	3	14	16	2	15	7.31E-05	1	1.5	207.	208.( 5.)	239.( 7.)	3.	3.( 1.)	9.( 1.)
859.66022	11	17	4	14	16	1	15	2.47E-05	3	2.9	209.	213.( 7.)	26.	26.( 4.)	38.( 7.)	
864.95886	6	11	9	3	10	6	4	1.00E-04	1	.5	505.	505.( 8.)	-100.	-98.( 8.)	-119.( 10.)	
865.44774	6	11	9	2	10	6	5	2.98E-04	2	.0	505.	490.( 6.)	-97.	-98.( 3.)	-112.( 3.)	
865.68649	50	18	5	14	17	2	15	6.85E-06	4	-1.3	181.	179.( 30.)	56.	56.( 4.)	-18.( 28.)	
871.25272	5	11	5	7	10	0	10	4.46E-04	3	-.2	682.	679.( 9.)	89.	90.( 4.)	103.( 4.)	
878.53526	3	12	4	8	11	1	11	2.53E-04	4	-.3	782.	760.( 20.)	123.	123.( 18.)	119.( 22.)	
881.08248	2	8	7	1	7	2	6	4.78E-05	2	-8.2	770.	770.( 40.)	18.	32.( 72.)	15.( 68.)	
883.07302	10	15	7	8	14	4	11	5.45E-05	3	-2.0	451.	460.( 20.)	196.	207.( 27.)	212.( 4.)	
883.84443	3	11	7	5	10	2	8	2.18E-04	2	-1.6	675.	669.( 6.)	76.	77.( 11.)	107.( 9.)	
887.22034	1	9	6	3	8	1	8	3.83E-04	4	1.4	721.	717.( 21.)	40.	40.( 10.)	46.( 5.)	
888.64348	10	12	9	4	11	6	5	1.54E-04	3	-.6	491.	506.( 6.)	-132.	-133.( 9.)	-142.( 6.)	
890.09262	10	12	9	3	11	6	6	5.22E-05	2	.5	491.	509.( 26.)	-131.	-136.( 14.)	-148.( 49.)	
891.30071	6	10	10	1	9	7	2	4.94E-05	3	.7	464.	462.( 6.)	-58.	-55.( 11.)	-82.( 12.)	
906.22785	32	17	2	15	16	1	16	1.07E-04	3	.0	209.	208.( 6.)	26.	26.( 3.)	33.( 9.)	
906.30900	31	17	3	15	16	0	16	3.52E-05	3	-1.3	211.	206.( 7.)	27.	27.( 6.)	40.( 10.)	
906.75277	10	15	8	7	14	5	10	2.28E-05	5	-.7	365.	368.( 10.)	48.	54.( 37.)	67.( 15.)	
908.95248	2	12	6	7	11	1	10	6.95E-04	4	-.3	599.	597.( 8.)	131.	130.( 5.)	154.( 5.)	
910.70960	25	18	4	15	17	1	16	1.44E-05	4	.0	197.	194.( 10.)	22.	32.( 18.)	59.( 30.)	
913.98290	8	13	9	4	12	6	7	6.53E-05	2	.6	451.	440.( 18.)	-118.	-113.( 10.)	-153.( 25.)	
918.48208	6	11	10	1	10	7	4	5.07E-05	3	-1.8	450.	480.( 45.)	-117.	-120.( 13.)	-92.( 46.)	
922.13539	6	12	7	6	11	2	9	3.44E-04	4	-1.9	610.	610.( 14.)	121.	123.( 6.)	149.( 6.)	
924.98770	2	9	7	2	8	2	7	1.83E-04	3	-5.2	707.	700.( 15.)	29.	25.( 8.)	39.( 17.)	
941.02233	10	14	5	9	13	2	12	4.53E-05	2	-2.7	730.	721.( 30.)	151.	151.( 234.)	145.( 145.)	
948.26294	5	12	5	8	11	0	11	4.33E-04	2	-3.3	660.	664.( 19.)	77.	78.( 9.)	84.( 7.)	
955.25188	5	10	6	4	9	1	9	7.56E-05	2	2.3	688.	692.( 50.)	52.	53.( 10.)	64.( 50.)	
959.18542	32	18	2	16	17	1	17	7.58E-06	4	-3.3	199.	196.( 23.)	45.	70.( 46.)	54.( 54.)	
959.22783	36	18	3	16	17	0	17	2.30E-05	3	-2.3	190.	193.( 14.)	34.	34.( 7.)	44.( 1.)	
971.36473	5	10	8	3	9	3	6	5.00E-05	3	-8.1	750.	730.( 40.)	-22.	-25.( 13.)	-22.( 11.)	
973.48325	4	13	6	8	12	1	11	7.00E-05	3	-4.3	575.	580.( 26.)	148.	147.( 7.)	179.( 2.)	
975.94547	3	13	4	9	12	1	12	1.66E-04	2	-5.0	714.	720.( 20.)	22.	22.( 5.)	20.( 19.)	
1000.28891	10	12	8	5	11	3	8	4.90E-05	3	1.1	729.	729.( 30.)	73.	83.( 41.)	74.( 5.)	
1017.45276	5	14	7	8	13	2	11	4.32E-05	2	.2	500.	504.( 40.)	176.	183.( 36.)	181.( 90.)	
1029.49646	3	11	6	5	10	1	10	9.35E-05	2	-4.4	644.	654.( 15.)	76.	77.( 1.)	65.( 27.)	
1042.52515	6	14	6	9	13	1	12	5.50E-05	3	-3.1	550.	541.( 36.)	158.	160.( 28.)	157.( 44.)	

 $b^o$  and  $d^o$  in  $\text{cm}^{-1}/\text{atm.} \times 10^4$  at 296 K.Strengths in  $\text{cm}^{-2}/\text{atm.}$  at 296K, ts is the estimated uncertainty in the observed strength in percent, (o-c)† is the percent difference between the observed and computed strength. Computed strength derived from parameters given in ref. 13Positions and un in  $\text{cm}^{-1}$ . un is the estimated uncertainty in the line positions  $\times 10^5$ . The computed values are derived from the energy levels given in Table 2 in ref 13 along with the estimated uncertainties in the levels.

\*asterisks denote doubled absorptions with the quantum assignment given for the stronger transition.

The strength given represents the sum of the strengths of the two comparable transitions.

 $b^o(\text{sm})$  and  $d^o(\text{sm})$  are smoothed values derived from hand plots of the observed coefficients

Values given within parentheses are estimated uncertainties in the last digits.

**Table 4. Observed pressure-broadened width and shift coefficients,  $b^\circ$  (HWHM) and  $d^\circ$ , of  $H_2^{18}O$  and  $H_2^{16}O$  broadened by  $N_2$  in  $\text{cm}^{-1}/\text{atm}$ .**

computed position	upper J	K <sub>a</sub>	K <sub>c</sub>	lower J	K <sub>a</sub>	K <sub>c</sub>	band	$b^\circ(H_2^{18}O)$	$b^\circ(H_2^{16}O)$	$d^\circ(H_2^{18}O)$	$d^\circ(H_2^{16}O)$
1282.80633	8	4	5	9	5	4	2	719. ( 15.)	693. ( 28.)	-566. ( 108.)	-633. ( 12.)
1302.69588	7	3	5	8	4	4	2	887. ( 7.)	912. ( 43.)	-654. ( 16.)	-609. ( 26.)
1308.45837	7	5	3	8	6	2	2	476. ( 15.)	515. ( 20.)	114. ( 79.)	19. ( 82.)
1308.63417	7	5	2	8	6	3	2	513. ( 3.)	528. ( 25.)	150. ( 34.)	85. ( 40.)
1309.25601	7	4	4	8	5	3	2	631. ( 6.)	647. ( 20.)	-164. ( 31.)	-258. ( 48.)
1311.04237	7	6	1	8	7	2	2	379. ( 14.)	424. ( 44.)	-85. ( 88.)	-233. ( 19.)
1312.42260	13	0	13	14	1	14	2	131. ( 13.)	106. ( 3.)	-107. ( 54.)	8. ( 13.)
1312.63258	6	2	5	7	3	4	2	953. ( 19.)	968. ( 12.)	-235. ( 118.)	-136. ( 24.)
1312.94534	7	4	3	8	5	4	2	715. ( 14.)	720. ( 12.)	666. ( 18.)	590. ( 51.)
1313.69566	5	1	5	6	2	4	2	1023. ( 20.)	1033. ( 59.)	-280. ( 29.)	-150. ( 60.)
1332.61790	12	1	12	13	0	13	2	128. ( 13.)	125. ( 6.)	-160. ( 80.)	-176. ( 41.)
1332.73471	6	5	2	7	6	1	2	453. ( 7.)	491. ( 6.)	91. ( 62.)	145. ( 35.)
1334.31031	6	4	3	7	5	2	2	622. ( 11.)	622. ( 17.)	161. ( 43.)	62. ( 25.)
1335.37557	6	4	2	7	5	3	2	681. ( 1.)	687. ( 12.)	458. ( 20.)	425. ( 25.)
1335.45793	6	6	1	7	7	0	2	315. ( 29.)	314. ( 25.)	-350. ( 61.)	-458. ( 33.)
1335.51770	6	3	4	7	4	3	2	824. ( 13.)	841. ( 10.)	-526. ( 2.)	-626. ( 39.)
1350.75024	6	3	3	7	4	4	2	883. ( 13.)	883. ( 9.)	601. ( 10.)	433. ( 30.)
1352.63884	11	0	11	12	1	12	2	173. ( 3.)	167. ( 9.)	-170. ( 17.)	-179. ( 42.)
1352.65879	11	1	11	12	0	12	2	179. ( 9.)	159. ( 12.)	-227. ( 24.)	-196. ( 64.)
1356.84386	5	2	4	6	3	3	2	964. ( 12.)	945. ( 21.)	-12. ( 2.)	-115. ( 40.)
1357.16194	5	5	0	6	6	1	2	416. ( 12.)	420. ( 20.)	-248. ( 66.)	-167. ( 207.)
1363.95106	5	3	3	6	4	2	2	809. ( 11.)	805. ( 13.)	-64. ( 130.)	-325. ( 30.)
1364.24474	12	1	12	12	2	11	2	265. ( 6.)	268. ( 6.)	-302. ( 58.)	-361. ( 12.)
1367.99222	9	2	7	10	3	8	2	725. ( 13.)	737. ( 18.)	-1262. ( 28.)	-1301. ( 109.)
1368.92858	4	1	4	5	2	3	2	1060. ( 6.)	1052. ( 8.)	-140. ( 36.)	-220. ( 20.)
1369.42164	5	3	2	6	4	3	2	855. ( 8.)	856. ( 7.)	450. ( 54.)	410. ( 32.)
1372.49562	10	0	10	11	1	11	2	217. ( 1.)	224. ( 8.)	-149. ( 15.)	-181. ( 35.)
1372.53904	10	1	10	11	0	11	2	226. ( 4.)	226. ( 3.)	-147. ( 6.)	-196. ( 40.)
1382.33613	7	2	5	8	3	6	2	880. ( 24.)	870. ( 9.)	-64. ( 22.)	-91. ( 67.)
1391.32591	4	3	1	5	4	2	2	812. ( 6.)	812. ( 10.)	476. ( 41.)	397. ( 25.)
1391.79874	9	2	8	10	1	9	2	375. ( 22.)	402. ( 4.)	204. ( 49.)	225. ( 14.)
1392.15725	9	0	9	10	1	10	2	295. ( 6.)	303. ( 3.)	-144. ( 21.)	-200. ( 30.)
1392.25375	9	1	9	10	0	10	2	298. ( 5.)	303. ( 5.)	-147. ( 43.)	-190. ( 20.)
1393.88010	4	2	3	5	3	2	2	953. ( 17.)	966. ( 5.)	-325. ( 65.)	-365. ( 25.)
1400.54004	5	2	3	6	3	4	2	973. ( 12.)	966. ( 12.)	170. ( 43.)	105. ( 25.)
1404.59618	8	1	7	9	2	8	2	558. ( 25.)	585. ( 10.)	-1080. ( 40.)	-1230. ( 10.)
1405.72603	10	1	10	10	2	9	2	396. ( 6.)	410. ( 6.)	-162. ( 15.)	-215. ( 30.)
1407.29380	5	0	5	5	3	2	2	1000. ( 24.)	1010. ( 15.)	-838. ( 25.)	-499. ( 58.)
1410.11420	8	2	7	9	1	8	2	499. ( 3.)	515. ( 7.)	511. ( 11.)	505. ( 30.)
1411.59148	8	0	8	9	1	9	2	392. ( 0.)	399. ( 12.)	-202. ( 19.)	-289. ( 38.)
1411.80823	8	1	8	9	0	9	2	401. ( 8.)	390. ( 8.)	-167. ( 25.)	-222. ( 15.)
1414.28464	4	2	2	5	3	3	2	956. ( 8.)	975. ( 12.)	226. ( 45.)	258. ( 84.)
1417.80331	3	1	3	4	2	2	2	1036. ( 10.)	1065. ( 22.)	-252. ( 32.)	-282. ( 40.)
1420.72168	8	3	6	9	2	7	2	805. ( 2.)	826. ( 8.)	955. ( 84.)	935. ( 22.)
1424.87419	3	2	2	4	3	1	2	935. ( 9.)	934. ( 8.)	-206. ( 65.)	-315. ( 25.)
1426.13131	9	1	9	9	2	8	2	487. ( 10.)	500. ( 15.)	-118. ( 11.)	-235. ( 110.)
1427.19628	9	0	9	9	1	8	2	523. ( 6.)	519. ( 5.)	203. ( 107.)	225. ( 20.)
1429.41119	7	2	6	8	1	7	2	660. ( 26.)	670. ( 6.)	800. ( 84.)	749. ( 29.)
1446.15187	8	1	8	8	2	7	2	610. ( 21.)	600. ( 11.)	-193. ( 97.)	-300. ( 23.)
1448.39021	8	0	8	8	1	7	2	640. ( 2.)	654. ( 7.)	374. ( 62.)	325. ( 25.)
1449.50217	6	0	6	7	1	7	2	655. ( 20.)	670. ( 7.)	-454. ( 20.)	-550. ( 40.)
1454.08566	4	1	3	5	2	4	2	1002. ( 6.)	1000. ( 12.)	-203. ( 31.)	-285. ( 10.)
1465.54541	7	1	7	7	2	6	2	750. ( 0.)	744. ( 6.)	-265. ( 79.)	-282. ( 35.)
1474.27379	5	2	4	6	1	5	2	930. ( 3.)	935. ( 15.)	661. ( 126.)	382. ( 31.)
1479.08375	9	1	8	9	2	7	2	714. ( 5.)	744. ( 20.)	554. ( 74.)	481. ( 15.)
1480.76467	6	3	4	7	2	5	2	890. ( 21.)	926. ( 20.)	276. ( 68.)	342. ( 50.)
1483.17142	8	2	7	8	3	6	2	683. ( 17.)	704. ( 8.)	-829. ( 54.)	-891. ( 61.)
1483.92606	6	1	6	6	2	5	2	840. ( 7.)	832. ( 20.)	-329. ( 21.)	-412. ( 66.)
1484.97158	4	0	4	5	1	5	2	1000. ( 10.)	980. ( 30.)	-524. ( 52.)	-619. ( 28.)
1492.30853	6	0	6	6	1	5	2	875. ( 14.)	944. ( 53.)	68. ( 36.)	288. ( 44.)
1493.27695	1	1	1	2	2	0	2	1069. ( 19.)	1072. ( 9.)	-441. ( 65.)	-575. ( 22.)
1495.08173	9	3	7	9	4	6	2	658. ( 21.)	657. ( 43.)	-1205. ( 166.)	-1369. ( 244.)
1500.76533	5	1	5	5	2	4	2	907. ( 6.)	911. ( 20.)	-382. ( 68.)	-437. ( 28.)
1502.28511	8	3	6	8	4	5	2	673. ( 6.)	705. ( 15.)	-938. ( 8.)	-839. ( 84.)

Table 4. continued

computed position	upper			lower			band	$b^O(H_2^{18}O)$	$b^O(H_2^{16}O)$	$d^O(H_2^{18}O)$	$d^O(H_2^{16}O)$
	J	K <sub>a</sub>	K <sub>c</sub>	J	K <sub>a</sub>	K <sub>c</sub>					
1505.04989	8	4	5	8	5	4	2	634.(-24.)	640.(-25.)	-79.(-167.)	-254.(-120.)
1506.25124	6	4	2	6	5	1	2	667.(-4.)	710.(-14.)	395.(-46.)	410.(-110.)
1510.18452	6	3	4	6	4	3	2	745.(-9.)	759.(-8.)	-441.(-34.)	-655.(-35.)
1511.59436	5	3	3	5	4	2	2	758.(-8.)	768.(-4.)	-185.(-26.)	-235.(-35.)
1513.19751	4	3	1	4	4	0	2	830.(-5.)	846.(-6.)	301.(-53.)	218.(-24.)
1523.48213	3	2	2	3	3	1	2	935.(-5.)	947.(-8.)	38.(-77.)	-170.(-16.)
1530.77350	3	2	2	4	1	3	2	1070.(-11.)	1065.(-40.)	447.(-75.)	643.(-66.)
1535.38411	4	0	4	4	1	3	2	1070.(-14.)	1065.(-35.)	-42.(-74.)	-124.(-30.)
1561.33561	2	2	1	3	1	2	2	1071.(-13.)	1061.(-10.)	285.(-33.)	260.(-60.)
1581.70194	4	3	1	5	2	4	2	998.(-11.)	950.(-16.)	517.(-77.)	495.(-28.)
1582.99336	3	3	1	4	2	2	2	964.(-2.)	995.(-25.)	282.(-118.)	286.(-22.)
1587.46207	3	2	1	4	1	4	2	1028.(-0.)	1032.(-6.)	358.(-73.)	374.(-15.)
1593.77442	5	4	1	6	3	4	2	824.(-16.)	838.(-15.)	136.(-74.)	10.(-50.)
1593.86968	2	2	0	3	1	3	2	1045.(-6.)	1078.(-34.)	351.(-16.)	467.(-142.)
1597.47966	3	1	3	2	2	0	2	1052.(-7.)	1085.(-25.)	-157.(-63.)	-265.(-20.)
1599.00706	3	3	0	4	2	3	2	950.(-13.)	960.(-15.)	361.(-95.)	400.(-50.)
1603.28788	4	1	4	3	2	1	2	1036.(-4.)	1047.(-6.)	-118.(-151.)	-185.(-20.)
1611.27965	4	4	1	5	3	2	2	910.(-13.)	929.(-48.)	279.(-43.)	153.(-5.)
1621.58525	2	0	2	1	1	1	2	1097.(-14.)	1124.(-35.)	-196.(-19.)	-195.(-40.)
1628.06006	1	1	1	0	0	0	2	1087.(-29.)	1125.(-20.)	485.(-16.)	375.(-50.)
1631.92221	3	1	2	2	2	1	2	1038.(-8.)	1053.(-14.)	-56.(-24.)	-140.(-50.)
1632.78633	4	2	2	3	3	1	2	994.(-7.)	1003.(-25.)	-64.(-5.)	-107.(-98.)
1633.46596	5	3	3	4	4	0	2	803.(-10.)	832.(-49.)	-76.(-135.)	-35.(-41.)
1647.01984	4	1	3	4	0	4	2	1060.(-9.)	1075.(-20.)	275.(-74.)	680.(-50.)
1656.42459	6	3	4	5	4	1	2	794.(-2.)	812.(-20.)	-390.(-8.)	-455.(-20.)
1661.81258	6	2	4	6	1	5	2	995.(-12.)	1018.(-20.)	735.(-51.)	700.(-20.)
1663.49794	4	1	3	3	2	2	2	1035.(-8.)	1028.(-20.)	-176.(-29.)	-245.(-35.)
1664.00865	3	2	2	3	1	3	2	1010.(-0.)	1045.(-16.)	456.(-44.)	551.(-139.)
1666.63105	5	2	3	4	3	2	2	1020.(-7.)	1012.(-15.)	15.(-51.)	-93.(-156.)
1672.60477	7	3	4	7	2	5	2	969.(-15.)	982.(-20.)	650.(-86.)	646.(-50.)
1681.41067	4	3	1	4	2	2	2	1025.(-18.)	1005.(-8.)	171.(-40.)	140.(-30.)
1682.34766	7	2	5	7	1	6	2	897.(-6.)	910.(-7.)	625.(-8.)	641.(-32.)
1690.23822	5	2	4	5	1	5	2	905.(-1.)	912.(-10.)	542.(-112.)	541.(-30.)
1692.69691	3	3	1	3	2	2	2	970.(-16.)	975.(-15.)	301.(-61.)	264.(-39.)
1701.97039	5	3	3	5	2	4	2	874.(-15.)	887.(-8.)	577.(-116.)	585.(-35.)
1702.39648	6	2	4	5	3	3	2	940.(-21.)	948.(-20.)	69.(-59.)	88.(-45.)
1706.83589	6	2	5	6	1	6	2	810.(-3.)	788.(-7.)	445.(-48.)	425.(-10.)
1716.99647	7	1	6	7	0	7	2	780.(-13.)	774.(-8.)	-478.(-17.)	-527.(-31.)
1719.76445	7	4	3	7	3	4	2	965.(-26.)	970.(-7.)	-150.(-52.)	-189.(-53.)
1722.53721	7	3	5	7	2	6	2	741.(-5.)	754.(-9.)	981.(-69.)	965.(-9.)
1723.92040	6	1	5	5	2	4	2	907.(-6.)	933.(-10.)	-662.(-94.)	-729.(-30.)
1736.32719	4	4	0	4	3	1	2	879.(-4.)	883.(-8.)	-33.(-4.)	-81.(-70.)
1737.00719	8	3	6	8	2	7	2	639.(-0.)	670.(-20.)	972.(-21.)	1000.(-20.)
1737.71687	4	4	1	4	3	2	2	869.(-2.)	868.(-7.)	-121.(-43.)	-150.(-35.)
1738.37868	5	4	2	5	3	3	2	845.(-2.)	838.(-7.)	-41.(-32.)	-50.(-60.)
1738.65936	7	2	5	6	3	4	2	910.(-8.)	905.(-15.)	-303.(-83.)	-304.(-66.)
1740.13094	6	4	3	6	3	4	2	779.(-7.)	808.(-15.)	63.(-18.)	7.(-70.)
1740.65075	5	2	4	4	1	3	2	983.(-11.)	1005.(-11.)	395.(-52.)	329.(-26.)
1743.70041	7	4	4	7	3	5	2	718.(-20.)	750.(-19.)	205.(-117.)	138.(-55.)
1761.12848	9	1	9	8	0	8	2	405.(-5.)	407.(-4.)	219.(-14.)	154.(-29.)
1763.23999	9	2	8	9	1	9	2	479.(-30.)	480.(-12.)	-10.(-60.)	-104.(-52.)
1767.72589	7	2	6	6	1	5	2	900.(-17.)	894.(-7.)	391.(-15.)	359.(-25.)
1770.21125	10	4	7	10	3	8	2	531.(-23.)	546.(-12.)	1252.(-102.)	1293.(-104.)
1773.31285	4	2	2	3	1	3	2	1050.(-4.)	1044.(-10.)	549.(-7.)	518.(-42.)
1777.66254	10	0	10	9	1	9	2	293.(-1.)	310.(-7.)	-7.(-27.)	-85.(-25.)
1777.73559	10	1	10	9	0	9	2	299.(-1.)	300.(-10.)	56.(-44.)	-20.(-15.)
1781.57269	10	1	9	10	0	10	2	347.(-3.)	388.(-7.)	-543.(-543.)	-530.(-19.)
1782.36240	7	5	2	7	4	3	2	812.(-26.)	827.(-17.)	-405.(-73.)	-305.(-163.)
1782.69005	10	2	9	10	1	10	2	387.(-6.)	403.(-12.)	-63.(-11.)	-119.(-8.)
1784.74737	6	5	1	6	4	2	2	757.(-30.)	784.(-7.)	-286.(-93.)	-330.(-40.)
1785.56314	5	5	0	5	4	1	2	738.(-16.)	755.(-20.)	-531.(-65.)	-624.(-44.)
1785.87666	6	5	2	6	4	3	2	698.(-6.)	734.(-8.)	-465.(-24.)	-505.(-22.)
1786.02583	7	5	3	7	4	4	2	703.(-4.)	721.(-25.)	-419.(-34.)	-583.(-164.)
1791.11422	4	3	1	3	2	2	2	960.(-10.)	958.(-5.)	282.(-23.)	184.(-25.)
1794.04169	11	0	11	10	1	10	2	260.(-2.)	240.(-15.)	-93.(-21.)	-170.(-16.)
1794.07383	11	1	11	10	0	10	2	250.(-15.)	240.(-15.)	-187.(-60.)	-139.(-20.)
1795.36926	9	1	8	8	2	7	2	519.(-3.)	514.(-5.)	-673.(-27.)	-752.(-16.)
1800.03872	9	2	8	8	1	7	2	620.(-3.)	620.(-12.)	659.(-2.)	624.(-28.)
1801.67912	5	3	3	4	2	2	2	995.(-5.)	985.(-7.)	66.(-11.)	65.(-30.)
1806.57442	9	2	7	8	3	6	2	794.(-13.)	798.(-7.)	-1608.(-22.)	-1668.(-834.)
1810.11466	12	0	12	11	1	11	2	144.(-14.)	166.(-5.)	-372.(-186.)	-300.(-80.)
1810.12905	12	1	12	11	0	11	2	169.(-2.)	173.(-8.)	-260.(-2.)	-280.(-20.)
1815.45025	10	1	9	9	2	8	2	407.(-5.)	406.(-8.)	-445.(-7.)	-549.(-20.)

Table 4. continued

computed position	upper J	K <sub>a</sub>	K <sub>c</sub>	lower J	K <sub>a</sub>	K <sub>c</sub>	band	b <sup>O</sup> (H <sub>2</sub> <sup>18</sup> O)	b <sup>O</sup> (H <sub>2</sub> <sup>16</sup> O)	d <sup>O</sup> (H <sub>2</sub> <sup>18</sup> O)	d <sup>O</sup> (H <sub>2</sub> <sup>16</sup> O)
1816.05895	6	3	4	5	2	3	2	998.( 12.)	988.( 15.)	3.( 45.)	60.( 30.)
1817.72908	10	2	9	9	1	8	2	466.( 4.)	458.( 6.)	471.( 28.)	498.( 10.)
1821.83447	5	3	2	4	2	3	2	975.( 13.)	955.( 7.)	747.( 49.)	296.( 44.)
1822.09412	5	2	3	4	1	4	2	1027.( 9.)	1043.( 7.)	-135.( 149.)	485.( 30.)
1825.89055	13	0	13	12	1	12	2	125.( 10.)	139.( 7.)	-324.( 162.)	-200.( 25.)
1825.89714	13	1	13	12	0	12	2	146.( 15.)	139.( 7.)	-246.( 123.)	-184.( 94.)
1827.89718	7	3	5	6	2	4	2	950.( 9.)	954.( 18.)	20.( 45.)	-10.( 50.)
1834.93513	4	4	0	3	3	1	2	779.( 2.)	770.( 10.)	-265.( 4.)	-255.( 45.)
1835.77116	11	2	10	10	1	9	2	326.( 9.)	334.( 4.)	240.( 18.)	176.( 17.)
1838.46848	8	3	6	7	2	5	2	895.( 5.)	885.( 4.)	260.( 18.)	262.( 15.)
1841.37795	14	1	14	13	0	13	2	113.( 9.)	100.( 6.)	-320.( 10.)	-470.( 36.)
1849.33870	9	3	7	8	2	6	2	859.( 18.)	860.( 12.)	544.( 23.)	549.( 25.)
1853.34753	12	1	11	11	2	10	2	224.( 12.)	227.( 12.)	-282.( 28.)	-326.( 39.)
1853.87481	12	2	11	11	1	10	2	240.( 10.)	249.( 5.)	-7.( 32.)	-25.( 35.)
1856.57499	15	0	15	14	1	14	2	88.( 9.)	100.( 3.)	-321.( 161.)	-266.( 10.)
1858.27243	5	4	2	4	3	1	2	900.( 3.)	890.( 17.)	-187.( 21.)	-246.( 20.)
1871.49483	16	1	16	15	0	15	2	75.( 7.)	80.( 4.)	-363.( 56.)	-414.( 12.)
1871.63712	13	1	12	12	2	11	2	180.( 3.)	163.( 10.)	-306.( 15.)	-288.( 32.)
1871.89194	13	2	12	12	1	11	2	174.( 11.)	170.( 12.)	-282.( 109.)	-172.( 40.)
1877.77701	6	2	4	5	1	5	2	1027.( 5.)	1040.( 30.)	265.( 86.)	325.( 25.)
1879.78473	6	4	3	5	3	2	2	920.( 7.)	912.( 7.)	-90.( 46.)	-115.( 15.)
1885.76960	6	4	2	5	3	3	2	802.( 9.)	826.( 5.)	-73.( 16.)	-99.( 52.)
1889.75625	14	2	13	13	1	12	2	139.( 14.)	141.( 14.)	-247.( 23.)	-260.( 34.)
1893.42146	12	3	10	11	2	9	2	390.( 28.)	471.( 8.)	917.( 0.)	977.( 22.)
1894.90457	5	3	3	4	0	4	2	953.( 10.)	1005.( 40.)	472.( 146.)	520.( 18.)
1897.85207	7	4	4	6	3	3	2	905.( 7.)	925.( 11.)	-25.( 31.)	-50.( 30.)
1902.60678	7	3	4	6	2	5	2	970.( 2.)	961.( 20.)	489.( 25.)	531.( 29.)
1911.86900	8	4	5	7	3	4	2	915.( 17.)	925.( 9.)	-272.( 34.)	-219.( 25.)
1913.93136	7	4	3	6	3	4	2	815.( 4.)	812.( 4.)	247.( 38.)	180.( 32.)
1932.11673	6	5	2	5	4	1	2	691.( 2.)	702.( 7.)	-758.( 23.)	-782.( 28.)
1932.39067	6	5	1	5	4	2	2	672.( 7.)	683.( 10.)	-695.( 2.)	-743.( 19.)
1937.17078	6	3	4	5	0	5	2	950.( 7.)	930.( 15.)	740.( 68.)	575.( 74.)
1938.69576	7	2	5	6	1	6	2	950.( 3.)	949.( 35.)	296.( 94.)	455.( 67.)
1946.19840	8	4	4	7	3	5	2	840.( 10.)	825.( 35.)	887.( 98.)	819.( 42.)
1955.73421	7	5	3	6	4	2	2	749.( 1.)	754.( 27.)	-596.( 7.)	-660.( 38.)
1957.02922	7	5	2	6	4	3	2	710.( 5.)	708.( 11.)	-676.( 6.)	-701.( 38.)
1977.62983	8	5	4	7	4	3	2	810.( 16.)	800.( 8.)	-511.( 13.)	-475.( 25.)
1981.99053	8	5	3	7	4	4	2	673.( 14.)	708.( 17.)	-584.( 116.)	-654.( 59.)
1984.28881	7	3	5	6	0	6	2	852.( 22.)	856.( 10.)	680.( 680.)	711.( 19.)
1984.55327	9	4	5	8	3	6	2	822.( 30.)	840.( 18.)	1194.( 107.)	1257.( 33.)
2005.64427	7	6	1	6	5	2	2	533.( 19.)	557.( 8.)	-1078.( 136.)	-1038.( 126.)
2008.08026	9	5	4	8	4	5	2	662.( 7.)	685.( 13.)	-366.( 36.)	-373.( 25.)
2029.99775	8	6	3	7	5	2	2	576.( 6.)	588.( 9.)	-1053.( 40.)	-1077.( 48.)
2052.99412	7	7	0	6	6	1	2	353.( 7.)	366.( 46.)	-1193.( 51.)	-1191.( 596.)
2054.51439	9	6	3	8	5	4	2	570.( 18.)	592.( 16.)	-1060.( 70.)	-1079.( 22.)
2078.16700	8	7	2	7	6	1	2	430.( 18.)	403.( 20.)	-922.( 163.)	-994.( 497.)
2123.62138	8	8	1	7	7	0	2	281.( 21.)	277.( 6.)	-1068.( 1.)	-1101.( 10.)

computed positions are H<sub>2</sub><sup>18</sup>O frequencies from Toth, ref. (15) and represents zero pressure frequencies  
 b<sup>O</sup> values × 10<sup>4</sup> and d<sup>O</sup> values × 10<sup>5</sup>

values given within parentheses are uncertainties in the last digit(s)

**Table 5. Observed values of air-broadened width (HWHM) and shift coefficients,  $b^\circ$  and  $d^\circ$ , for the (020)-(010) and (100)-(010) bands of  $H_2^{16}O$  and smoothed values from the (010)-(000) band of  $H_2^{16}O$ .**

upper						lower		computed	$b^\circ$		$d^\circ$	
J	K <sub>a</sub>	K <sub>c</sub>	J	K <sub>a</sub>	K <sub>c</sub>	band	position	smoothed	observed	smoothed	observed	
5	1	4	4	2	3	3	1657.43826	921.	831.( 83.)	-542.	-1634.( 817.)	
2	1	2	1	0	1	3	1619.36015	1034.	997.( 36.)	440.	455.( 69.)	
4	1	4	3	0	3	3	1649.80758	954.	898.( 90.)	520.	559.( 80.)	
5	1	5	4	0	4	3	1665.02900	847.	830.( 14.)	470.	448.( 47.)	
6	1	6	5	0	5	3	1681.09233	720.	726.( 36.)	371.	456.( 228.)	
9	1	9	8	0	8	3	1731.46770	367.	338.( 34.)	83.	75.( 38.)	
2	0	2	1	1	1	3	1586.99407	979.	992.( 22.)	-138.	-63.( 40.)	
3	0	3	2	1	2	3	1612.18109	969.	941.( 7.)	-215.	-178.( 36.)	
5	0	5	4	1	4	3	1657.38969	807.	770.( 20.)	27.	254.( 22.)	
6	0	6	5	1	5	3	1677.22329	689.	683.( 10.)	111.	178.( 32.)	
9	0	9	8	1	8	3	1731.03699	360.	337.( 17.)	10.	-28.( 38.)	
11	0	11	10	1	10	3	1764.59770	217.	203.( 5.)	-210.	-224.( 65.)	
2	2	1	1	1	0	4	2148.18853	949.	973.( 63.)	88.	-338.( 311.)	
3	2	2	2	1	1	4	2165.22562	980.	961.( 192.)	115.	-710.( 710.)	
11	2	10	10	1	9	3	1813.23330	314.	334.( 67.)	105.	0.( 0.)	
4	3	2	3	2	1	3	1778.53096	859.	850.( 19.)	40.	-165.( 106.)	
8	3	6	7	2	5	3	1831.99400	828.	710.( 71.)	210.	0.( 0.)	
3	3	0	2	2	1	3	1758.33308	830.	808.( 11.)	255.	138.( 24.)	
5	3	2	4	2	3	3	1814.71471	864.	817.( 12.)	285.	262.( 50.)	
6	3	3	5	2	4	3	1849.64108	873.	807.( 47.)	450.	597.( 213.)	
7	3	4	6	2	5	3	1891.55090	865.	843.( 12.)	426.	678.( 67.)	
4	4	1	3	3	0	3	1839.14695	708.	659.( 5.)	-333.	-326.( 56.)	
5	4	2	4	3	1	3	1862.95596	764.	753.( 12.)	-227.	-497.( 249.)	
6	4	3	5	3	2	3	1885.02081	801.	740.( 40.)	-125.	-276.( 22.)	
4	4	0	3	3	1	3	1839.32460	707.	640.( 64.)	-277.	-327.( 48.)	
5	4	1	4	3	2	3	1864.17126	714.	707.( 19.)	-250.	-318.( 42.)	
7	4	3	6	3	4	3	1916.68206	740.	595.( 17.)	142.	46.( 23.)	
5	5	1	4	4	0	3	1920.88522	559.	477.( 33.)	-600.	-906.( 906.)	
5	5	0	4	4	1	3	1920.91362	596.	487.( 14.)	-667.	-924.( 69.)	
7	5	2	6	4	3	3	1970.25549	581.	562.( 16.)	-641.	-685.( 117.)	
6	6	1	5	5	0	3	2000.90318	423.	422.( 21.)	-808.	-987.( 104.)	
6	6	0	5	5	1	3	2001.01686	410.	410.( 35.)	-808.	-1224.( 97.)	
7	6	1	6	5	2	3	2026.12071	489.	445.( 17.)	-986.	-656.( 402.)	
7	7	0	6	6	1	3	2078.23027	309.	339.( 34.)	-1100.	-950.( 950.)	
1	1	0	1	0	1	3	1583.35619	1020.	1016.( 7.)	550.	688.( 75.)	
2	1	1	2	0	2	3	1590.38134	1027.	1010.( 101.)	543.	645.( 323.)	
3	1	2	3	0	3	3	1602.72984	1008.	948.( 11.)	442.	550.( 65.)	
5	1	4	5	0	5	3	1644.68805	880.	843.( 84.)	14.	0.( 0.)	
3	2	1	3	1	2	3	1620.33582	952.	905.( 19.)	200.	178.( 39.)	
4	2	2	4	1	3	3	1620.46950	943.	856.( 8.)	532.	437.( 42.)	
5	2	3	5	1	4	3	1626.05912	930.	899.( 16.)	540.	606.( 31.)	
7	2	5	7	1	6	3	1657.75822	833.	770.( 77.)	458.	918.( 459.)	
2	2	1	2	1	2	3	1639.08392	967.	935.( 37.)	335.	323.( 112.)	
4	2	3	4	1	4	3	1660.46767	891.	846.( 9.)	405.	422.( 43.)	
6	2	5	6	1	6	3	1693.41744	724.	668.( 67.)	350.	102.( 51.)	
7	3	4	7	2	5	3	1660.24435	897.	815.( 82.)	542.	614.( 307.)	
6	3	4	6	2	5	3	1703.68008	761.	743.( 74.)	567.	672.( 336.)	
7	4	3	7	3	4	3	1725.51901	846.	894.( 89.)	-148.	-298.( 149.)	
6	2	5	7	1	6	3	1426.44052	696.	683.( 21.)	730.	634.( 95.)	
8	2	7	9	1	8	3	1383.65338	460.	444.( 13.)	337.	341.( 155.)	
1	0	1	2	1	2	4	2003.39231	1032.	1013.( 101.)	-450.	-1326.( 663.)	
2	0	2	3	1	3	3	1482.47745	1016.	981.( 64.)	-540.	0.( 0.)	
3	0	3	4	1	4	4	1969.77534	947.	868.( 55.)	-602.	-902.( 45.)	
4	0	4	5	1	5	3	1452.46878	841.	834.( 45.)	-604.	-521.( 261.)	
7	0	7	8	1	8	3	1400.94225	460.	442.( 14.)	-443.	-391.( 64.)	
8	0	8	9	1	9	3	1382.42327	355.	343.( 16.)	-335.	-317.( 48.)	
10	0	10	11	1	11	3	1344.45745	203.	219.( 0.)	-171.	-417.( 138.)	
11	0	11	12	1	12	3	1325.15851	153.	152.( 7.)	-241.	-198.( 19.)	
1	1	1	2	0	2	3	1531.12878	989.	981.( 98.)	79.	26.( 13.)	
2	1	2	3	0	3	4	2003.00020	981.	938.( 94.)	28.	-347.( 174.)	

Table 5. continued

upper J K <sub>a</sub> K <sub>c</sub>	lower J K <sub>a</sub> K <sub>c</sub>	band	computed position	b° smoothed	b° observed	d° smoothed	d° observed
3 1 3	4 0 4	3	1482.53989	919.	825. ( 7.)	140.	-115. ( 111.)
4 1 4	5 0 5	3	1460.93771	819.	807. ( 1.)	-56.	-128. ( 64.)
5 1 5	6 0 6	3	1440.69963	698.	672. ( 13.)	-135.	-255. ( 28.)
6 1 6	7 0 7	3	1421.21592	573.	550. ( 11.)	-185.	-249. ( 56.)
7 1 7	8 0 8	3	1402.05545	455.	442. ( 15.)	-256.	-256. ( 51.)
8 1 8	9 0 9	3	1382.97009	353.	337. ( 10.)	-269.	-292. ( 9.)
10 1 10	11 0 11	3	1344.59245	205.	192. ( 8.)	-238.	-251. ( 61.)
11 1 11	12 0 12	3	1325.22708	156.	163. ( 33.)	-270.	0. ( 0.)
2 1 1	3 2 2	3	1441.55833	935.	957. ( 22.)	-70.	0. ( 0.)
3 1 2	4 2 3	3	1426.61018	919.	898. ( 20.)	-191.	-182. ( 42.)
4 1 3	5 2 4	3	1414.42228	897.	876. ( 14.)	-335.	-235. ( 40.)
5 1 4	6 2 5	3	1404.16852	848.	800. ( 80.)	-479.	-406. ( 203.)
7 1 6	8 2 7	3	1384.17032	651.	622. ( 10.)	-907.	-918. ( 124.)
1 1 1	2 2 0	3	1452.60700	969.	989. ( 99.)	-594.	0. ( 0.)
3 1 3	4 2 2	3	1377.08997	961.	876. ( 88.)	-275.	-499. ( 250.)
4 1 4	5 2 3	3	1327.73552	965.	940. ( 18.)	-195.	-189. ( 87.)
6 1 6	7 2 5	3	1209.26625	891.	838. ( 84.)	-345.	-599. ( 300.)
2 2 0	3 3 1	3	1409.75920	835.	827. ( 83.)	44.	-39. ( 15.)
4 2 2	5 3 3	3	1369.53145	865.	811. ( 30.)	144.	114. ( 248.)
5 2 3	6 3 4	3	1355.20985	876.	839. ( 66.)	13.	221. ( 111.)
2 2 1	3 3 0	3	1408.52958	820.	800. ( 12.)	-187.	-194. ( 42.)
3 2 2	4 3 1	3	1381.76361	837.	806. ( 16.)	-310.	-274. ( 98.)
4 2 3	5 3 2	3	1351.57016	864.	810. ( 15.)	-365.	-426. ( 72.)
3 3 0	4 4 1	3	1371.03947	652.	608. ( 12.)	168.	112. ( 40.)
4 3 1	5 4 2	3	1347.03163	714.	664. ( 4.)	281.	464. ( 46.)
5 3 2	6 4 3	3	1324.34949	763.	696. ( 7.)	281.	514. ( 19.)
3 3 1	4 4 0	3	1370.89240	666.	600. ( 9.)	-10.	60. ( 15.)
4 3 2	5 4 1	3	1346.00353	674.	630. ( 18.)	-5.	76. ( 35.)
6 3 4	7 4 3	3	1292.82692	739.	655. ( 18.)	-587.	-710. ( 21.)
5 4 1	6 5 2	3	1316.12962	560.	497. ( 50.)	250.	286. ( 143.)
6 4 2	7 5 3	3	1292.01131	601.	550. ( 55.)	306.	342. ( 223.)
5 4 2	6 5 1	3	1315.99316	531.	548. ( 110.)	137.	388. ( 388.)
6 4 3	7 5 2	3	1291.34791	552.	508. ( 12.)	40.	-84. ( 35.)
6 5 1	7 6 2	3	1291.93029	437.	400. ( 80.)	240.	0. ( 0.)
7 5 2	8 6 3	3	1267.51319	473.	377. ( 38.)	40.	-219. ( 110.)
6 5 2	7 6 1	3	1291.90521	435.	400. ( 40.)	142.	-276. ( 395.)
6 6 1	7 7 0	3	1297.13464	296.	306. ( 31.)	-471.	-458. ( 229.)
4 0 4	5 3 3	3	1248.89010	927.	839. ( 168.)	-490.	-367. ( 367.)
5 0 5	6 3 4	3	1207.27418	871.	737. ( 147.)	-623.	-918. ( 918.)
1 0 1	1 1 0	3	1534.93544	1001.	1015. ( 102.)	-665.	-490. ( 245.)
5 0 5	5 1 4	3	1478.12345	881.	856. ( 16.)	-77.	-79. ( 48.)
7 0 7	7 1 6	3	1428.87885	674.	670. ( 30.)	227.	478. ( 45.)
9 0 9	9 1 8	3	1380.62386	472.	450. ( 19.)	141.	107. ( 54.)
3 1 2	3 2 1	3	1515.29141	952.	957. ( 96.)	-558.	-758. ( 379.)
5 1 4	5 2 3	3	1511.48586	930.	878. ( 88.)	-577.	-556. ( 278.)
4 1 4	4 2 3	4	1969.55886	891.	901. ( 180.)	-215.	-364. ( 364.)
6 1 6	6 2 5	3	1440.57280	724.	694. ( 10.)	-350.	-340. ( 37.)
10 1 10	10 2 9	3	1356.03845	368.	369. ( 37.)	-231.	155. ( 78.)
3 2 1	3 3 0	3	1485.13358	868.	860. ( 30.)	-167.	-118. ( 63.)
4 2 3	4 3 2	3	1477.24877	847.	783. ( 15.)	-547.	-595. ( 65.)
8 2 7	8 3 6	3	1441.54070	605.	591. ( 8.)	-866.	-822. ( 411.)
4 3 1	4 4 0	3	1469.10832	768.	716. ( 72.)	124.	61. ( 31.)
7 3 4	7 4 3	3	1480.69774	812.	797. ( 80.)	115.	782. ( 391.)
5 3 3	5 4 2	3	1467.79752	727.	691. ( 69.)	-251.	-421. ( 211.)
6 3 4	6 4 3	3	1466.58460	700.	610. ( 25.)	-586.	-652. ( 103.)

 $b^o$  in  $\text{cm}^{-1}/\text{atm.} \times 10^4$  and  $d^o$  in  $\text{cm}^{-1}/\text{atm.} \times 10^5$ band notation: 3 represents the (020)-(010) band and 4 is the (100)-(010) band  
computed positions from Toth (14) and represents the zero pressure frequencies

**Table 6. Comparison of observed line strengths, ( $\text{cm}^{-2}/\text{atm.}$  at 296K), and air-broadened widths (HWHM),  $b^o$  ( $\text{cm}^{-1}/\text{atm.}$ ), of  $\text{H}_2^{16}\text{O}$  from this work with those from the study of Rinsland et al.<sup>a</sup>**

line position	upper				lower				line strength		$b^o$	
	J	K <sub>a</sub>	K <sub>c</sub>	J	K <sub>a</sub>	K <sub>c</sub>	this work	Rinsland	this work	Rinsland		
802.9900	13	7	6	12	4	9	7.85E-04(4)	7.94E-04(7.1)	0.0437(6)	0.0424(24)		
803.5464	11	8	3	10	5	6	1.35E-03(2)	1.39E-03(8.7)	0.0560(9)	0.0524(54)		
805.9937	16	3	13	15	2	14	1.12E-04(2)	1.11E-04(10.5)	0.0249(9)	0.0246(22)		
806.6956	17	4	13	16	3	14	3.76E-05(2)	4.03E-05(29.2)	0.0310(7)	0.0289(60)		
808.0379	16	4	13	15	1	14	3.35E-04(2)	3.33E-04(10.7)	0.0262(7)	0.0235(21)		
808.2802	8	7	2	7	2	5	3.90E-04(3)	3.88E-04(8.1)	0.0813(12)	0.0804(31)		
814.5170	12	8	5	11	5	6	6.24E-04(3)	6.27E-04(3.7)	0.0667(25)	0.0668(21)		
825.1627	8	6	2	7	1	7	1.66E-04(2)	1.63E-04(11.0)	0.0781(8)	0.0751(26)		
835.5530	14	8	7	13	5	8	8.31E-05(2)	8.01E-05(11.0)	0.0686(3)	0.0663(51)		
841.9028	7	7	0	6	2	5	5.48E-05(4)	5.08E-05(12.3)	0.0829(27)	0.0764(65)		
849.5795	11	6	6	10	1	9	6.14E-04(5)	6.00E-04(3.2)	0.0617(11)	0.0610(15)		
853.3766	14	6	8	13	3	11	1.04E-04(2)	9.83E-05(7.6)	0.0633(27)	0.0633(26)		
854.5833	13	5	8	12	2	11	7.42E-04(3)	7.26E-04(1.4)	0.0784(16)	0.0762(27)		
858.5429	17	3	14	16	2	15	7.31E-05(1)	7.34E-05(12.5)	0.0208(7)	0.0210(16)		
864.9589	11	9	3	10	6	4	1.00E-04(1)	9.75E-05(3.4)	0.0517(14)	0.0502(16)		
865.4477	11	9	2	10	6	5	2.98E-04(2)	2.91E-04(2.6)	0.0490(6)	0.0478(17)		
865.6865	18	5	14	17	2	15	6.85E-06(4)	7.63E-06(27.9)	0.0179(30)	0.0168(34)		
871.2527	11	5	7	10	0	10	4.46E-04(3)	4.40E-04(5.1)	0.0679(9)	0.0671(17)		
881.0825	8	7	1	7	2	6	4.78E-05(2)	4.70E-05(13.6)	0.0740(35)	0.0742(53)		
883.0730	15	7	8	14	4	11	5.45E-05(3)	5.02E-05(11.1)	0.0460(20)	0.0443(32)		
883.8444	11	7	5	10	2	8	2.18E-04(2)	2.17E-04(2.2)	0.0669(6)	0.0656(22)		
887.2203	9	6	3	8	1	8	3.83E-04(4)	3.88E-04(8.8)	0.0717(21)	0.0713(19)		
888.6435	12	9	4	11	6	5	1.54E-04(3)	1.52E-04(5.9)	0.0510(8)	0.0500(16)		
890.0926	12	9	3	11	6	5	5.22E-05(2)	5.13E-05(7.4)	0.0509(26)	0.0469(44)		
*896.5048	12	0	12	13	3	11	1.00E-05(3)	1.10E-05(26.8)	0.0357(71)	0.0371(114)		
*897.6940	12	1	12	13	2	11	3.01E-05(2)	3.09E-05(11.2)	0.0380(20)	0.0352(35)		
906.2278	17	2	15	16	1	16	1.07E-04(3)	1.07E-04(9.3)	0.0208(6)	0.0207(18)		
906.3090	17	3	15	16	0	16	3.52E-05(3)	3.63E-05(11.4)	0.0206(7)	0.0213(12)		
906.7528	15	8	7	14	5	10	2.28E-05(5)	2.23E-05(14.3)	0.0368(10)	0.0314(24)		
908.9525	12	6	7	11	1	10	6.95E-04(4)	6.77E-04(0.7)	0.0597(8)	0.0582(20)		
910.7096	18	4	15	17	1	16	1.44E-05(4)	1.50E-05(17.1)	0.0194(10)	0.0177(29)		
913.9829	13	9	4	12	6	7	6.53E-05(2)	6.60E-05(8.3)	0.0440(18)	0.0443(28)		
921.3978	15	6	9	14	3	12	5.53E-05(4)	5.70E-05(14.2)	0.0717(70)	0.0719(78)		
922.1354	12	7	6	11	2	9	3.44E-04(4)	3.36E-04(2.9)	0.0610(14)	0.0575(22)		
937.3195	14	9	5	13	6	8	7.30E-06(5)	7.39E-06(28.6)	0.0390(S)	0.0400(123)		
941.0223	14	5	9	13	2	12	4.53E-05(2)	4.32E-05(10.9)	0.0721(30)	0.0723(59)		
948.2629	12	5	8	11	0	11	4.33E-04(2)	4.28E-04(3.5)	0.0664(19)	0.0634(14)		
*953.3674	11	0	11	12	3	10	1.19E-04(1)	1.18E-04(4.0)	0.0406(23)	0.0399(15)		
*954.1095	8	4	5	9	7	2	8.70E-06(5)	8.68E-06(37.8)	0.0652(S)	0.0574(135)		
955.2518	10	6	4	9	1	9	7.56E-05(2)	7.19E-05(8.3)	0.0692(50)	0.0687(44)		
*955.6870	11	1	11	12	2	10	4.01E-05(3)	3.88E-05(5.8)	0.0402(33)	0.0398(37)		
971.3647	10	8	3	9	3	6	5.00E-05(3)	4.78E-05(11.1)	0.0730(40)	0.0755(39)		
*971.6561	12	2	11	13	3	10	3.50E-05(2)	3.38E-05(12.2)	0.0477(S)	0.0456(41)		
973.4832	13	6	8	12	1	11	7.00E-05(3)	6.99E-05(5.2)	0.0580(26)	0.0561(23)		
973.9833	10	7	3	9	2	8	5.17E-05(2)	5.03E-05(7.7)	0.0589(59)	0.0646(22)		
*977.4315	8	1	8	9	4	5	6.50E-05(2)	6.02E-05(17.3)	0.0784(78)	0.0792(85)		
984.1118	11	8	4	10	3	7	1.97E-05(3)	2.02E-05(19.8)	0.0719(144)	0.0765(79)		
*998.8096	8	3	6	9	6	3	5.42E-05(3)	5.92E-05(6.7)	0.0637(22)	0.0649(48)		
1000.2889	12	8	5	11	3	8	4.90E-05(3)	4.80E-05(18.8)	0.0729(73)	0.0691(91)		
*1010.0282	10	0	10	11	3	9	1.41E-04(2)	1.41E-04(3.8)	0.0462(11)	0.0458(16)		
*1010.8133	11	1	10	12	4	9	1.31E-04(2)	1.31E-04(4.5)	0.0425(7)	0.0429(3)		
*1014.4752	10	1	10	11	2	9	4.33E-04(2)	4.38E-04(1.5)	0.0502(10)	0.0494(7)		
1017.4528	14	7	8	13	2	11	4.32E-05(2)	4.48E-05(11.2)	0.0504(40)	0.0509(28)		
*1017.8685	8	2	7	9	5	4	1.52E-04(3)	1.52E-04(5.6)	0.0699(17)	0.0679(28)		
1042.5251	14	6	9	13	1	12	5.50E-05(3)	5.42E-05(2.2)	0.0541(36)	0.0517(23)		
*1072.6135	10	2	8	11	5	7	7.57E-05(5)	7.41E-05(17.9)	0.0669(50)	0.0646(94)		
*1085.4363	5	3	2	6	6	1	5.30E-05(4)	5.30E-05(18.4)	0.0809(81)	0.0755(60)		
*1091.2049	10	2	9	11	3	8	6.80E-04(2)	6.67E-04(2.3)	0.0625(13)	0.0648(7)		
*1099.6793	9	2	7	10	5	6	5.30E-04(3)	5.27E-04(2.5)	0.0761(13)	0.0720(22)		
*1101.4506	6	2	5	7	5	2	5.38E-04(2)	5.40E-04(8.1)	0.0715(21)	0.0730(21)		
*1106.7439	9	1	8	10	4	7	1.56E-03(2)	1.56E-03(2.2)	0.0616(9)	0.0599(36)		
*1117.6170	11	3	9	12	4	8	7.76E-05(10)	7.36E-05(15.9)	0.0782(78)	0.0690(59)		
*1149.4692	8	1	7	9	4	6	1.37E-03(1)	1.34E-03(0.5)	0.0712(12)	0.0687(45)		

(a) from ref. (2)

\* represents transitions in the (010)-(000) band, other entries are transitions in the (000)-(000) band  
Values given within parenthesis pertain to uncertainties in percent for strengths and uncertainties in  
the last digit(s) for linewidths.

Entries for  $b^o$  from this work with (S) means that  $b^o$  was not measured in this work and the value given  
is the smoothed value taken from Tables 2 and 3.  
line positions computed from energy level values given in ref. (13)

Table 7. Comparison of air-and N<sub>2</sub>-broadened widths (HWHM), b°, of H<sub>2</sub><sup>16</sup>O between values of this work and those from other studies<sup>a</sup> using tunable diode lasers.

line position	upper			lower			buffer gas	b° (cm <sup>-1</sup> /atm.)	band
	J	K <sub>a</sub>	K <sub>c</sub>	J	K <sub>a</sub>	K <sub>c</sub>		this work	other <sup>a</sup>
922.1354	12	7	6	11	2	9	N2	0.0680(20)	0.0748
948.2629	12	5	8	11	0	11	N2	0.0750(15)	0.0738
959.1854	18	2	16	17	1	17	N2	0.0160(32)	0.0178
959.2278	18	3	16	17	0	17	N2	0.0177(43)	0.0178
1014.4752	10	1	10	11	2	9	N2	0.0562(11)	0.0588
1028.2717	11	7	4	10	2	9	N2	0.0663(48)	0.0717
1066.1546	9	0	9	10	3	8	N2	0.0605(13)	0.0489(33)
1652.4003	3	0	3	2	1	2	air	0.0948(20)	0.0897(15)
1652.4003	3	0	3	2	1	2	N2	0.1072(25)	0.0988(23)
1652.4740	6	2	5	5	3	2	air	0.0910(50)	0.0613(68)
1653.2671	2	1	2	1	0	1	air	0.1022(50)	0.0988(15)
1653.2671	2	1	2	1	0	1	N2	0.1175(45)	0.1094(23)
1653.4169	4	1	3	4	0	4	air	0.0936(15)	0.1049(46)
1653.4169	4	1	3	4	0	4	N2	0.1075(20)	0.1165(53)
1662.8093	2	2	1	2	1	2	air	0.0972(8)	0.0950(46)
1662.8093	2	2	1	2	1	2	N2	0.1068(10)	0.1049(53)
1668.2848	6	2	4	6	1	5	air	0.0888(25)	0.0851(46)
1668.2848	6	2	4	6	1	5	N2	0.1018(20)	0.0950(46)
*1879.0194	16	1	16	15	0	15	air	0.0072(2)	0.0070(8)
*1879.0194	16	1	16	15	0	15	N2	0.0080(4)	0.0071(8)
1879.2978	13	1	12	12	2	11	air	0.0163(18)	0.0171(18)
1879.2978	13	1	12	12	2	11	N2	0.0170(15)	0.0185(19)
1932.8027	16	1	15	15	2	14	air	0.0087(3)	0.0091(9)
1932.8027	16	1	15	15	2	14	N2	0.0100(6)	0.0096(10)
1932.8409	16	2	15	15	1	14	air	0.0085(3)	0.0091(9)
1932.8409	16	2	15	15	1	14	N2	0.0097(2)	0.0096(10)
1933.1654	9	4	6	8	3	5	air	0.0835(21)	0.0730(73)
1933.1654	9	4	6	8	3	5	N2	0.0915(30)	0.0811(81)
1941.6275	10	4	7	9	3	6	air	0.0754(11)	0.0810(81)
1941.6275	10	4	7	9	3	6	N2	0.0818(16)	0.0894(90)
1945.3402	7	2	5	6	1	6	air	0.0853(11)	0.0851(85)
1945.3402	7	2	5	6	1	6	N2	0.0949(35)	0.0925(101)
1946.3643	6	3	4	5	0	5	air	0.0841(25)	0.0885(89)
1946.3643	6	3	4	5	0	5	N2	0.0941(60)	0.0976(98)
1956.2334	4	4	1	3	1	2	N2	0.0999(17)	0.0958(101)
1966.2612	7	5	3	6	4	2	air	0.0682(12)	0.0532(64)
1967.4423	7	5	2	6	4	3	air	0.0608(11)	0.0532(64)

(a) other studies include the following:

for line positions less than 1070 cm<sup>-1</sup>, Eng and Mantz (9)

line positions >1662 cm<sup>-1</sup> and <1669 cm<sup>-1</sup> from Mucha (10)

for line positions greater than 1879 cm<sup>-1</sup>, Eng et al. (7)

Band notation: 1=(000)-(000) band, 2=(010)-(000) band

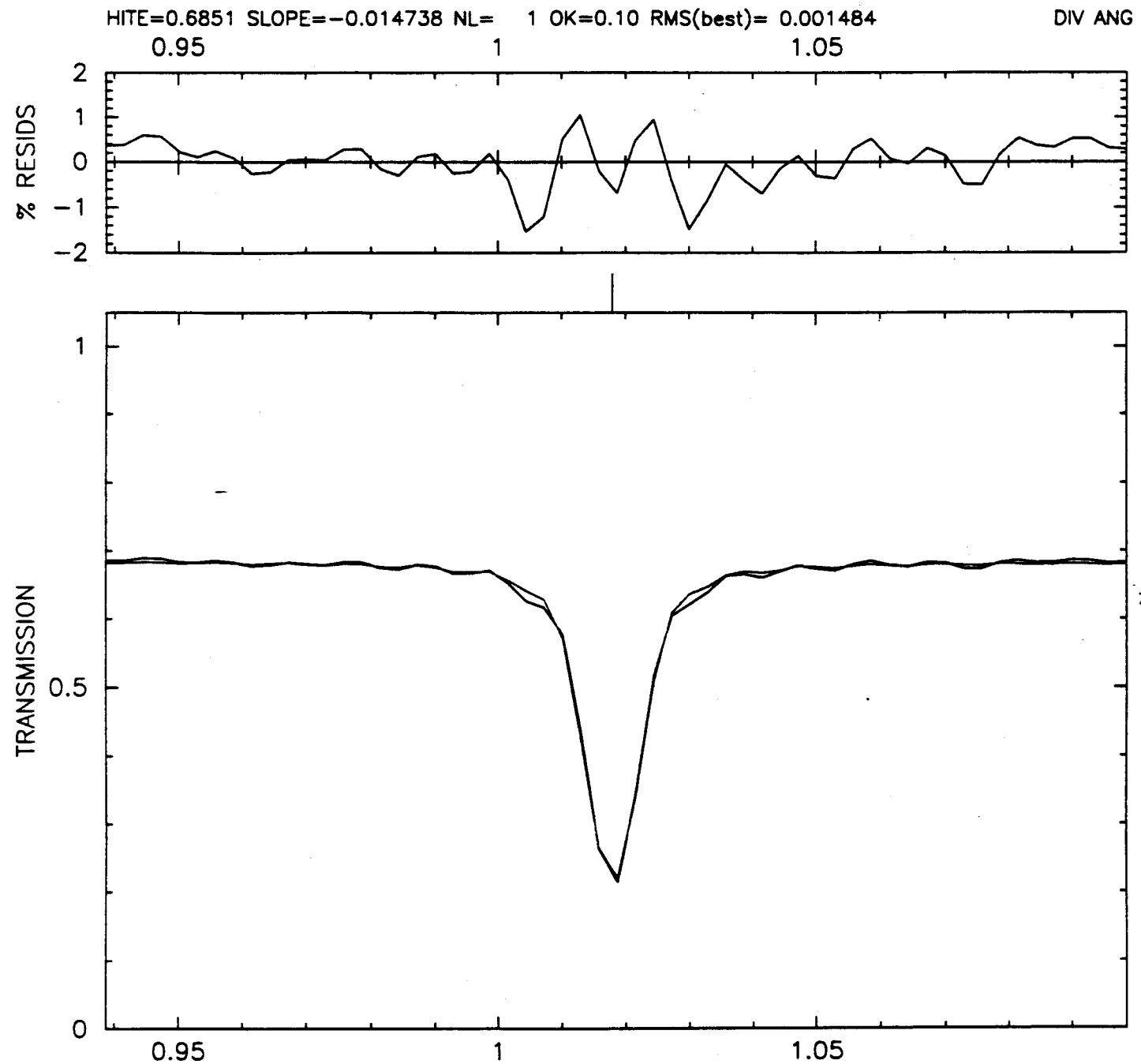
\* asterisk denotes doubled line with line position and quantum assignment pertaining to the stronger of the two comparable transitions

values given within parentheses are uncertainties in the last digits

line positions computed from energy level values given in ref. (13)

HITE=0.6851 SLOPE=-0.014738 NL= 1 OK=0.10 RMS(best)= 0.001484

DIV ANG



HITE=0.6879 SLOPE=-0.016337 NL= 1 OK=0.10 RMS(best)= 0.000234 DIV ANG

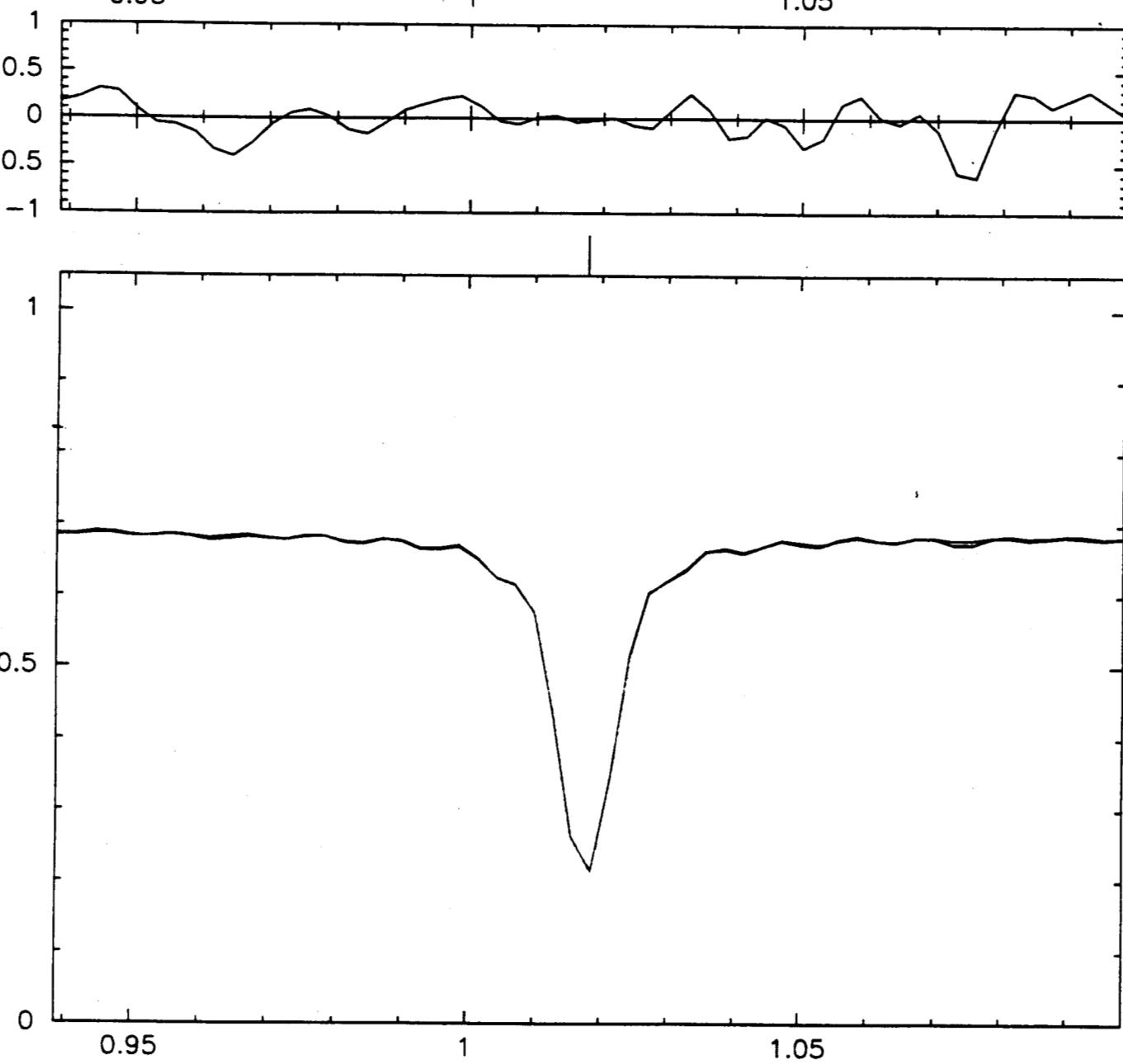
0.95

1

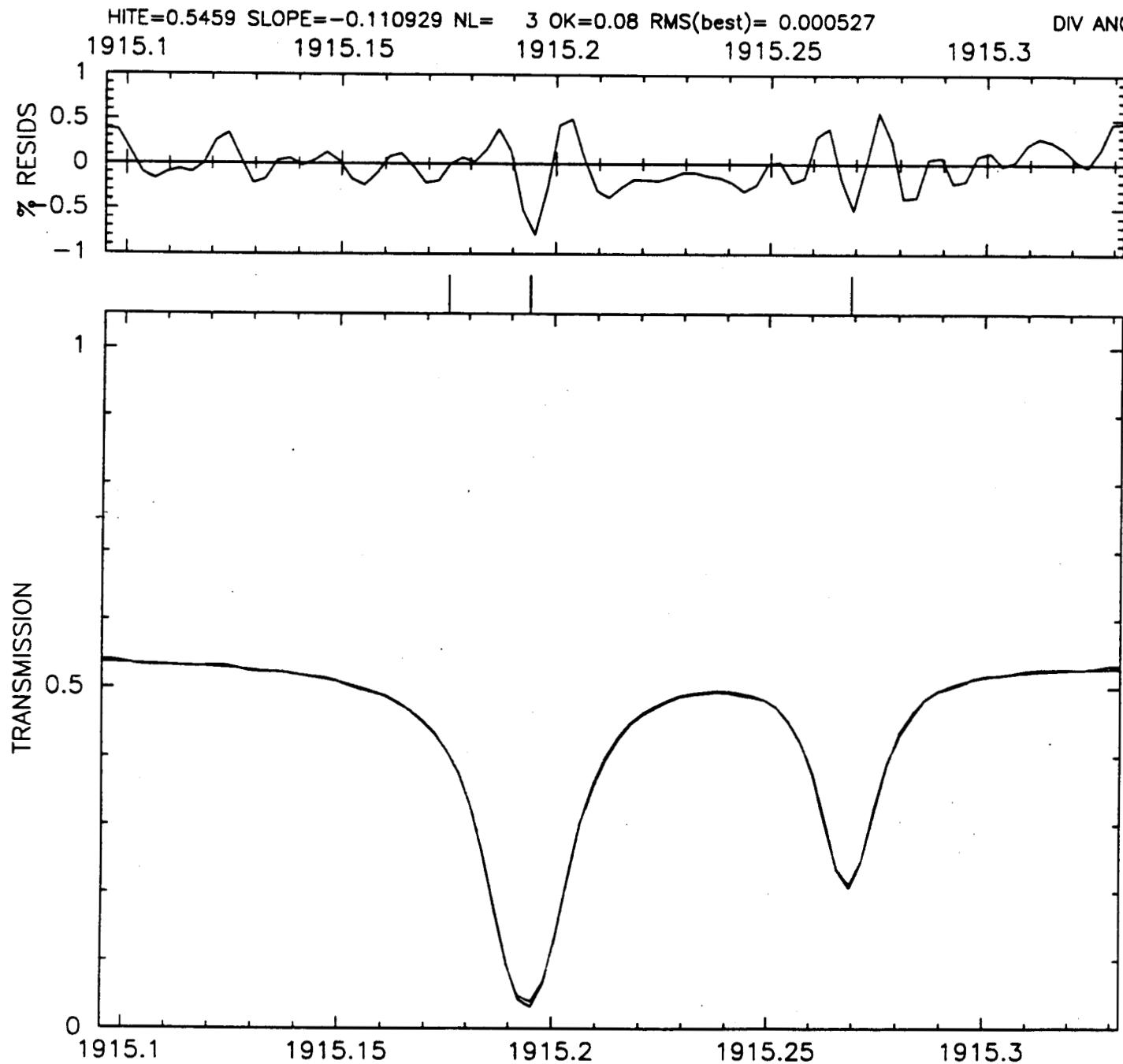
1.05

RESIDS

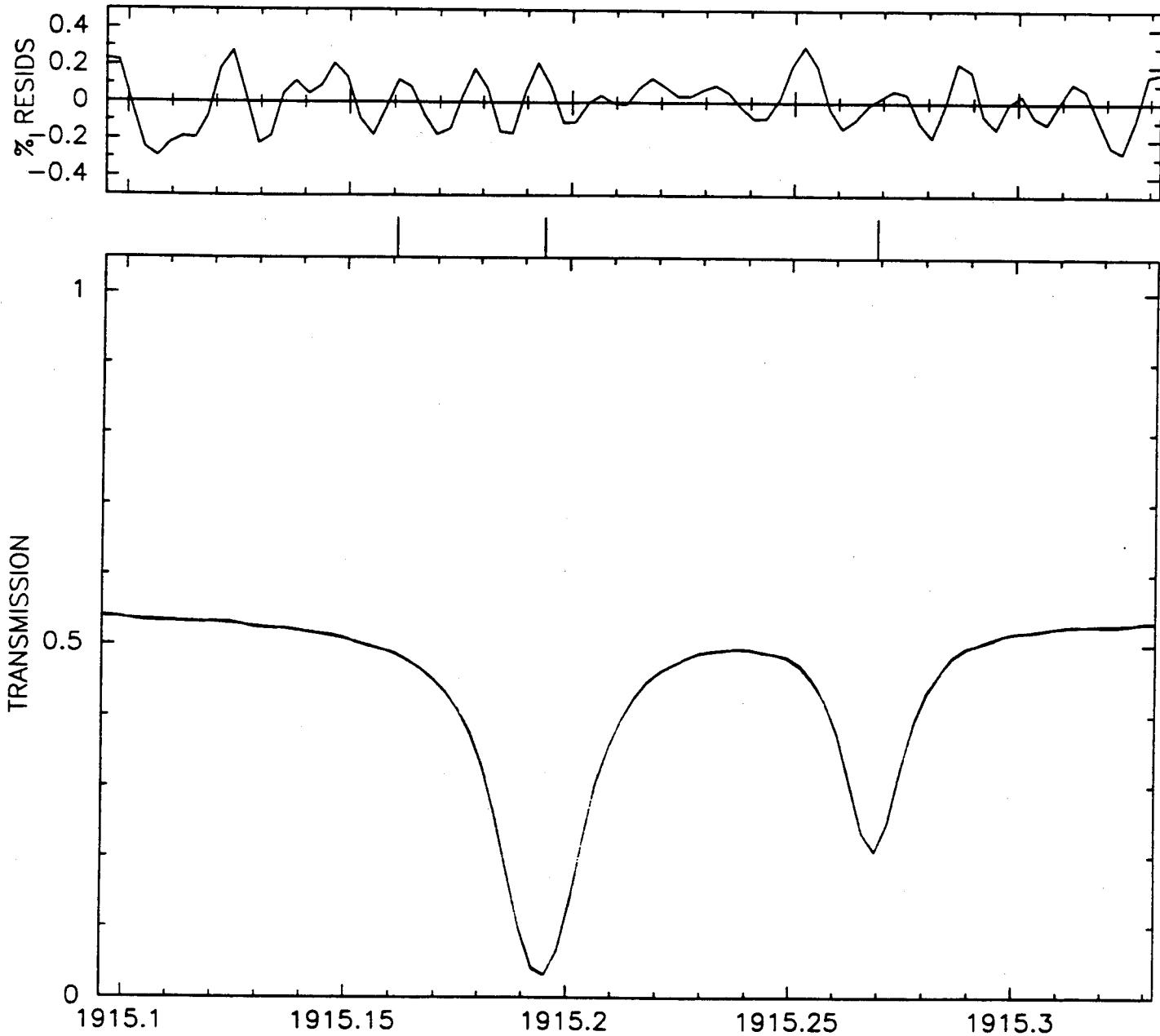
TRANSMISSION



HITE=0.5459 SLOPE=-0.110929 NL= 3 OK=0.08 RMS(best)= 0.000527 DIV ANG



HITE=0.5487 SLOPE=-0.098061 NL= 3 OK=0.08 RMS(best)= 0.000160  
1915.1 1915.15 1915.2 1915.25 1915.3 DIV ANG



HITE=0.7148 SLOPE=-0.021795 NL= 1 OK=0.10 RMS(best)= 0.000439

DIV ANG

0.95

1

1.05

